Ho'ōla Hou I Ke Kino O Kanaloa

Kaho'olawe Environmental Restoration Plan

Kaho'olawe Island Reserve Commission

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prepared for

Kahoʻolawe Island Reserve Commission
State of Hawaiʻi

by

Social Science Research Institute
University of Hawaiʻi at Mānoa

May 1998

Kūkulu Ke Ea A Kanaloa

The life and spirit of Kanaloa builds and takes form.

Pule Ho'ouluulu Ai

E Lono i ke ao ola i ka lani
E Kanaloa i ke kai nupanupa
E Kāne i ka wai ola
E Kū i ke kū uluulu

Eia ka 'ālana
He 'awa hiwa he niu hiwa
He i'a 'ula he kalo mana
E hō'ea mai ka 'āina a Kanaloa

(Ulu) mai ke ao poko
Mai ke ao loa
Mai ke ao lalapa
Mai ke ao 'eka'eka
E hō'ea mai ka ua a Kanaloa

Mai ke kai hohonu
Mai ke kai ko'ako'a
Mai ke kai 'ula'ula
Mai ke kai pū ea
E hō'ea mai ke kai a Kanaloa

Mai ka 'āina lau 'ai
Mai ka 'āina i ke kuauli
Mai ka 'āina i kahe ka wai
Mai ka 'āina i nā waimapuna
E hō'ea ke ola i ka 'āina a Kanaloa

Mai ka lā i ka hikina i napo'o o ka lā
I ka makani A'e o ulunui i ke Kona hili mai'a
E hō'ea mai a Kanaloa

O Lono in the life giving clouds of the heavens
O Kanaloa of the luxuriant seas
O Kāne of the life giving waters
O Kū of the upward growth

Here is my offering
Here the black 'awa, the black niu,
The red fish, the yellow taro
Bring life to the land of Kanaloa

From the short cloud
From the long cloud
From the flashing cloud
From the dirt colored cloud
Bring life to the rains of Kanaloa

From the deep blue sea
From the coral sea
From the red sea
From the life giving sea
Bring life to the seas of Kanaloa

From the land of the food plants
From the land of the verdant ridges
From the land of the streams
From the land of the springs that gush
Bring life to the land of Kanaloa

From the dawning of the sun to the setting of the sun
In the A'e trades of the north to whipping banana
prop south winds
Bring life to the land of Kanaloa

Haku 'ia e Nalani Kanaka'ole

Mahalo

The restoration planning process has involved hundreds of people from throughout the state who have shared their knowledge, ideas, and time. They include KIRC commissioners and staff, the US Navy, federal and state agency personnel, University of Hawai'i faculty and students, members of Protect Kaho'olawe 'Ohana, consultants and business people, private citizens, and members of various Hawaiian and non-profit organizations who care deeply about Kaho'olawe and its future.

First and foremost, we would like to acknowledge the work of those who came before us. Kūpuna taught about the land and our relationship to it. Ranchers initiated restoration activities in the first half of this century. Wes Wong and the staffs of the Department of Land and Natural Resources and USDA's Soil Conservation Service who began new efforts in the 1970s. The Protect Kaho'olawe 'Ohana worked with native plants and setting a precedent for a volunteer-based effort.

KIRC extends its warmest "mahalo" to everyone who has helped us to develop this document. Thank you as well to everyone who attended the public meetings and provided insightful comments on the draft. In particular, we would like to acknowledge the efforts of the following individuals.

Steering Committee

Nalani Kanaka'ole, KIRC Commissioner
Craig Neff, KIRC Commissioner
Keoni Fairbanks, KIRC Executive Director
Sam Gon, The Nature Conservancy of Hawai'i
Paul Higashino, KIRC Restoration Ecologist
Dan Holmes, Protect Kaho'olawe 'Ohana
Julie Leialoha, DLNR, Division of Forestry and Wildlife Hawai'i
Dennis Martinez, Indigenous Peoples Restoration Network
Benton Pang, 'Ahahui Mālama I Ka Lōkahi
Hannah Springer
Rene Sylva

Technical Advisory Committee

Kēhau Abad, University of Hawai'i, Department of Anthropology
Glenn Bauer, DLNR, Division of Water Resource Management O'ahu
Tom Giambelluca, University of Hawai'i, Department of Geography
Sam Gon, The Nature Conservancy of Hawai'i
Bob Hobdy, DLNR, Division of Forestry and Wildlife Maui
Julie Leialoha, DLNR, Division of Forestry and Wildlife Hawai'i
Patty Nakao
Chris Smith, USDA, Natural Resources Conservation Service
Cliff Smith, University of Hawai'i, Department of Botany

Technical Study Authors

Carter Atkinson, fauna
Paul Banko, fauna
Todd Boulanger, water
Gregory Brenner, fauna
Braven Cabigon, indigenous knowledge
Earl Campbell, fauna
Allison Chun Smith, lessons learned
Reginard David, fauna
Jonathan Deenik, erosion
Glenn Dolcemascolo, revegetation & erosion
John Egan, lessons learned
David Foote, fauna
Charlotte Forbes, fauna
Neal Fugiwara, erosion
Kanani Garcia, lessons learned
Tom Giambelluca, lessons learned
Samuel Gon, indigenous knowledge & revegetation
Shari-Monique Kahele, indigenous knowledge
John Lake, indigenous knowledge
Joel Lau, indigenous knowledge
Penny Levin, water & revegetation
Lloyd Loope, revegetation
Renee Louis, lessons learned
James Lum, erosion
Dennis Martinez, revegetation
Julianne Miller, indigenous knowledge
John Mink, water
Marie Morin, fauna
David Perry, revegetation
J. Lyman Perry, lessons learned
Thane Pratt, fauna
Michelle Reynolds, fauna
Fred Richardson, lessons learned
Glen Sakamoto, erosion
Chris Smith, erosion
William Steiner, fauna
Robert Sugihara, fauna
James Trappe, revegetation
Frederick Warshauer, fauna
Larry Yamamoto, erosion
George Yuen, water
Alan Ziegler, lessons learned

Meeting Attendees

Roxanne Adams
Lopaka Aiwohi
Palani Akina
Meiling Akuna
Robert Alcain
Mary Tuti Baker
Richard Bal
John and Dawn Balog
Hannah Bernard
Kim Bernie
Lawrence Burke
Herb Campos
Paul Campos
Mei-Ling Chang
John Chionchio

Sheila Conant
Pat Conant
Jennifer Crummer
Marko Cunningham
Charles Davidson
Felix Dellnig
Lucienne deNaie
Rose Marie Dewey
Capt. John Diggs
Geraldine Edlao
Roys Ellis
Mary Evanson
Evette Kamaka
Ron Fenstemacher
Lisa Ferentinos
Bill Garnett
Darby Gill
Daniel Grantham
Tim Gunter
Tim Hall
Mark Hanson
Isaac Harp
Robin Harrington
Chris Hart
Warren Haynes
Clyde Higa
Henry Hildebrand
Rebecca Hommon
Tamara Horcajo
Mary Ann Hutchinson
Billy Irvine
Jim Jacobi
Melinda Javier
Moke Ka'apana
Ka'alakea 'Ohana
Brad Kahaapo
Inola Kahanu
Yvette Kahauolopua
Galen Kahoohalahala
Mahealani Kaiaokamalie
Joyce Kainoa
Mona Kapaku
Keola Kauhaahaa
Rodney Kauhaahaa
Noren Kawakami
Kapua Kawelo
Kai Kealoha
Charles Keau
Robert Kekuna
Sue Kiang
Steven Kim
Dan Ko
Leslie Kuloloio
Manuel Kuloloio
Joseph Laford
Eric Lind
Charlie Lindsey
Bobby Lu'uwai
Attwood Makanani
Paul Malaspina
Charles Maxwell
Davianna McGregor
Art Mederios
Annette Mente
Steven Miller
Mike Minn Pohaku
Ed Misaki
Brian Miskae
Barrie Morgan
Dan Moriarity
Miho Morikawa
Jim Murphy
Mike Nahoopii
Kapiioho Naone
Joe Neilson
Mary Neilson
Vicki Newberry
Seija Nordling
John Obata
Gary Onuma
Samuel Pahuwai
Leimoni Pahuwai
Anna Palamino
Ed Pelekai
Cdr. Carol Petrea
Linda Pratt
Puahala 'Ohana
Gary Ray
Roland Reeve
Walter Ritte
Craig Roland
Kailani Ross
Adele Rugg
Christa Russell
Burt Sakata
Velma Santos
Jason Schwartz
Murv Sears
Diane Shepard
Lisa Stratton
Nobu Sudo
Metodio Tanora
Stepanie Tome
Jaeson Tremaine
Kalei Tsuha
Tim Tunison
Feliz Vellina
Chubby Vichie
Walter Victor
Keawe Vredenburg
Douglas Warne
Muriel Warne
Elaine Wender
Aaron Yasui
Alvin Yoshinaga

SSRI Project Staff

Michael Hamnett, principal investigator
Kristine Davidson Oh, project manager

Cheryl Anderson
Kathy Bryant
Williams Ganileo
Jill Keesbury
Penny Levin
Renee Louis
Phyllis Maike-Ganileo

KIRC Commissioners

Emmett Aluli, M.D.
A. Frenchy DeSoto
Palikapu Dedman
Nalani Kanaka'ole
Georgina Kawamura
Collette Machado
Craig Neff
Mike Wilson

KIRC Staff

Keoni Fairbanks
Paul Higashino
Allison Chun Smith
Lora Contreras
Stanton Enomoto
Kala Enos
Lehua Ford
Marc Hodges
Hōkūlani Holt-Padilla
Momi Lovell
Heidi Meeker
Deepak Neupane

photograph 1: **Kanapou Bay, Keoneuli Beach** (S. Enomoto)

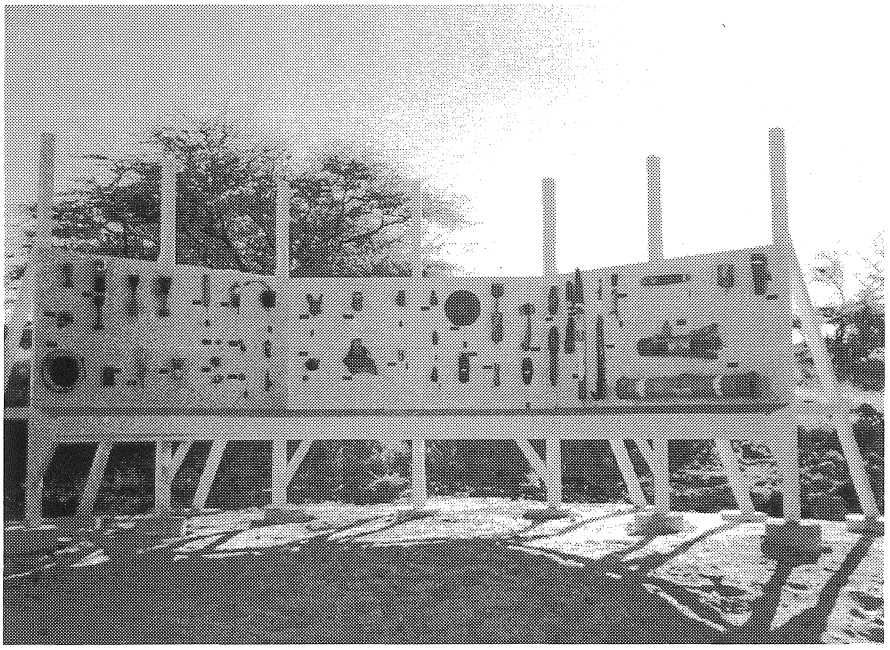
WARNING!

Unexploded Ordnance (UXO) on Kaho'olawe and its surrounding waters is an extreme safety threat.

Kaho'olawe was used as a military target for over 50 years. Nearly every type of conventional ordnance used by the US military and its allies since World War II has been dropped or fired on Kaho'olawe. Some of the ordnance remains buried or resting on the island's surface. Other items are washed down gullies and still other unexploded ordnance rests beneath the waters offshore. The possibility of unintentionally exploding these unstable, aging UXO is very real. Access to the land and waters of Kaho'olawe is restricted in the interest of public safety and conservation of the resources of the Reserve.

Neither the US government nor the State of Hawai'i are responsible for injury, death, or loss of property of unauthorized persons on the island or in Reserve waters.

photograph 2: **UXO Board at Honokanai'a** (C. Anderson)



Executive Summary

The Kaho'olawe Island Reserve Commission (KIRC) offers this document, *Ho'ōla Hou I Ke Kino O Kanaloa: Kaho'olawe Environmental Restoration Plan*, as a first step toward a comprehensive strategy for healing the kino of Kanaloa, the island of Kaho'olawe. *Ho'ōla Hou I Ke Kino O Kanaloa* constitutes the fourth major planning and policy document developed by KIRC.

The environment of Kaho'olawe is not static. Rather, Kaho'olawe is a living, dynamic, changing system, more complex than our limited understanding can fully comprehend. Intuitive insight, coupled with a sense of humility and an ability to remain flexible, provide an effective approach to healing the island. The Kaho'olawe Island Reserve Commission has identified several operating principles to guide the implementation of the restoration program:

- 'ike pāpālua;
- traditional ecological knowledge;
- systematic and connective approach;
- ecosystem succession;
- strategic restoration;
- observing and listening to the 'āina;
- community and native Hawaiian involvement;
- cooperation with the US Navy; and
- integrated research and action.

Restoration managers are confronted by numerous environmental, logistical, and financial challenges. An estimated 1.9 million tons of soil continues to be lost each year as a result of erosion. Severely eroded landscapes now cover approximately one-third of the island. Only 25 inches of rain falls at the summit, with perhaps less than 10 inches per year at the coast. Most plants on Kaho'olawe are hardy alien species that easily outcompete the few, small native plant populations for water and nutrients. Bombs litter the surface, and the cost of removal will be high. The archeological significance of the island requires extra effort during every step of the cleanup and restoration.

Kaho'olawe presents unique opportunities to learn about native plants and dryland ecosystems. Such knowledge can be applied to other islands in the future. Kaho'olawe's isolation from other islands has resulted in the absence of many alien plant and animal pests. Now that the goats are gone, the island has begun a natural recovery process. The restoration

effort offers numerous people the opportunity to contribute their expertise, time, and resources.

The healing of Kanaloa is a spiritual renewal manifested through cultural ceremonies and practices, as well as environmental restoration activities. The environmental restoration begins with the regeneration of soils, native plant and animal life, and the natural water system. Strategies addressing erosion control, botanical and faunal restoration, and enhancement of the natural water system have been introduced in this plan.

Infrastructure to support access to the island, water supply, equipment storage, staff accommodation, and roads will be needed for both the unexploded ordnance cleanup and the environmental restoration of Kaho'olawe. Thus, KIRC and the Navy will cooperatively design and construct infrastructure that serves both the cleanup and the longer-term environmental restoration.

People are needed to implement this plan and restore life to Kaho'olawe. KIRC has to ensure that its staff, volunteers, and potential future residents understand and support the cultural and spiritual underpinnings of the island's restoration.

Monitoring and evaluation will provide a picture of how Kaho'olawe is changing, the effects of erosion, pest control, and revegetation treatments, and a measurement of their success. This will allow restoration strategies to be modified and improved over time.

Many restoration activities will be done simultaneously and will follow an annual cycle. During the first two years, considerable effort must be devoted to developing infrastructure and to lay a firm foundation for the long-term restoration of the island.

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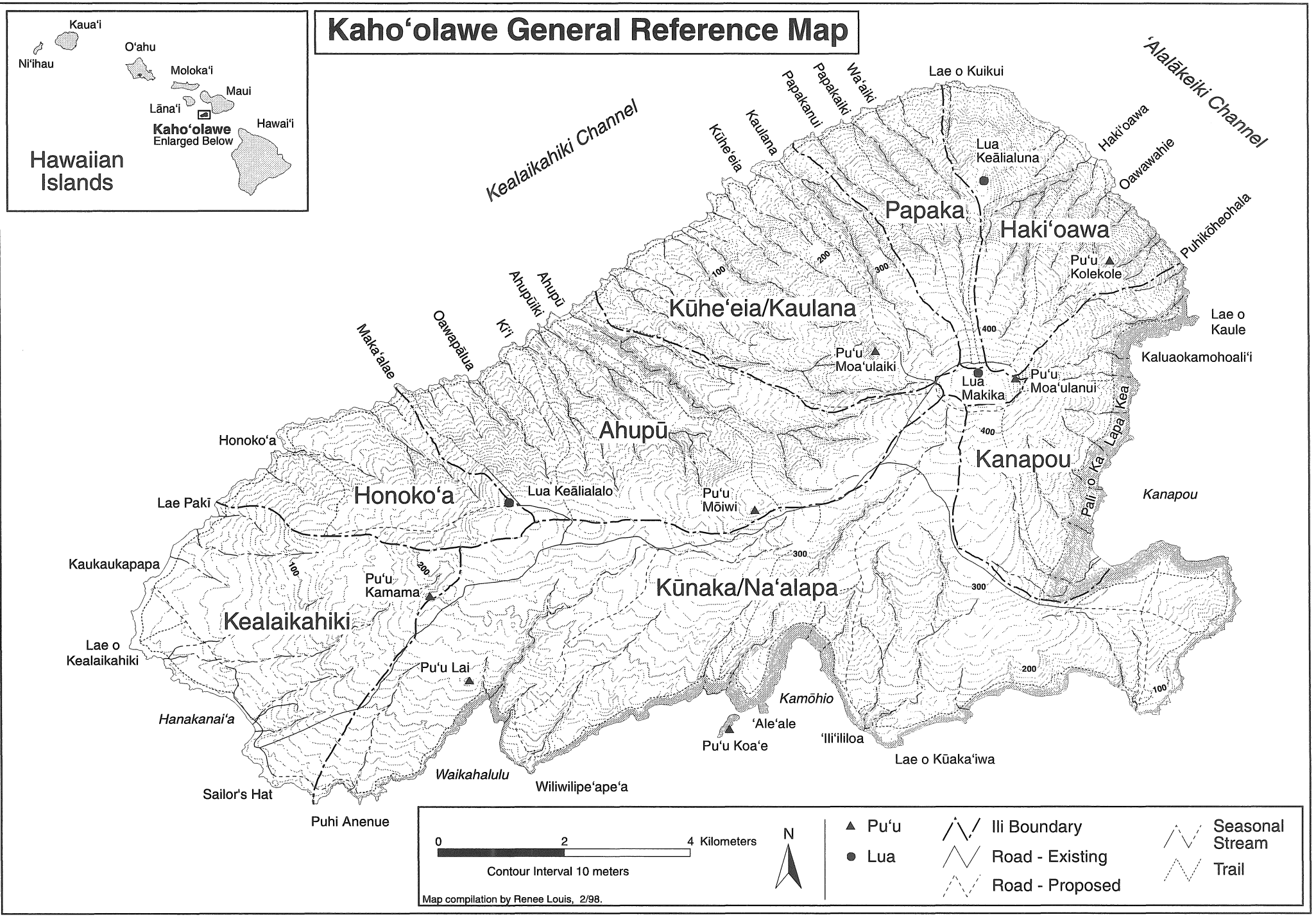
(Artist: Penny Levin)

Maps

(Cartographer: Renee Louis)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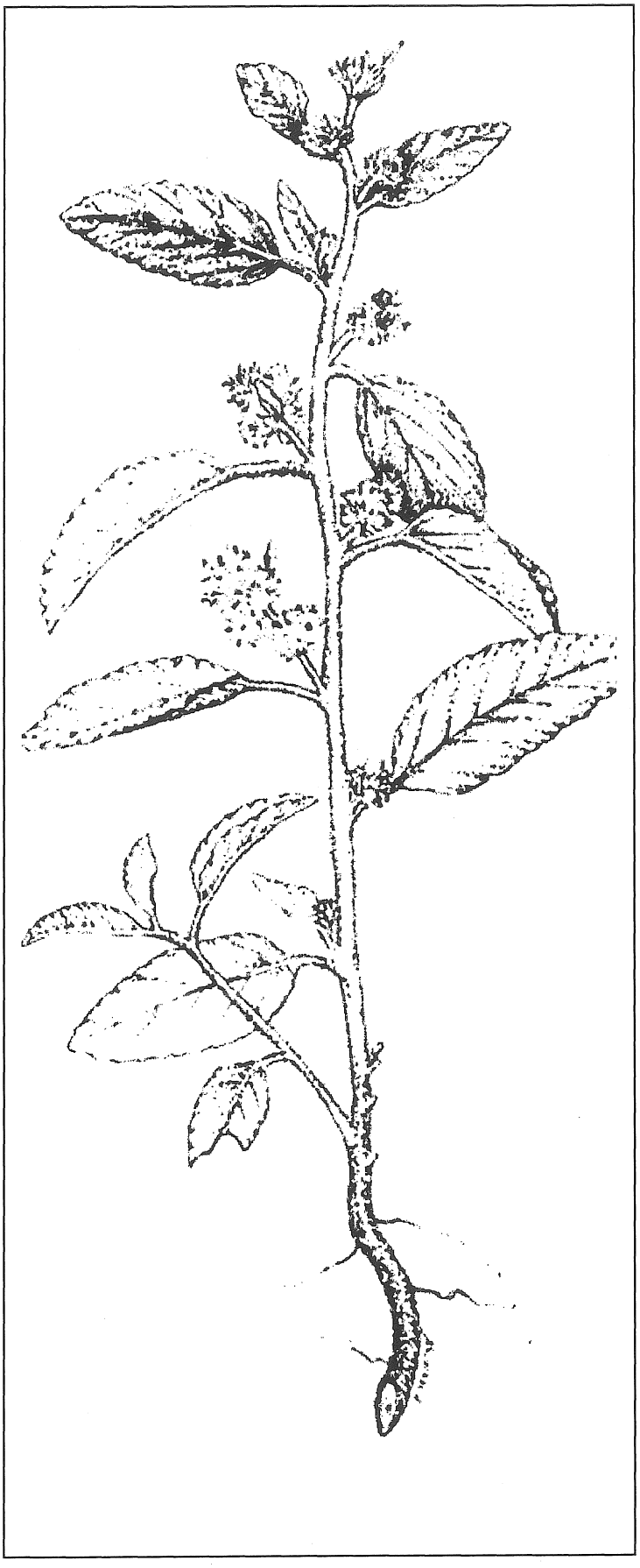
Papakaiki
Papakanui
Wa'aiki
Kaulana
Kūhe'eia
Ahupū
Ahupūiki
Ki'i
Oawapālua
Maka'alae
Honoko'a
Lae Pakī
Kaukaukapapa
Lae o Kealaikahiki
Hanakanai'a
Sailor's Hat
Puhi Anenue
Waikahalulu
Wiliwilipe'ape'a
Kamōhio
'Ale'ale
'Ili'iliiloa
Lae o Kūaka'iwa
Lāpa Kea
Pali o Ka
Kanapou
100
200
300
400
0
2
4 Kilometers
Contour Interval 10 meters
N
Pu'u
Lua
Ili Boundary
Road - Existing
Road - Proposed
Seasonal Stream
Trail
Map compilation by Renee Louis, 2/98.



Restoration Framework

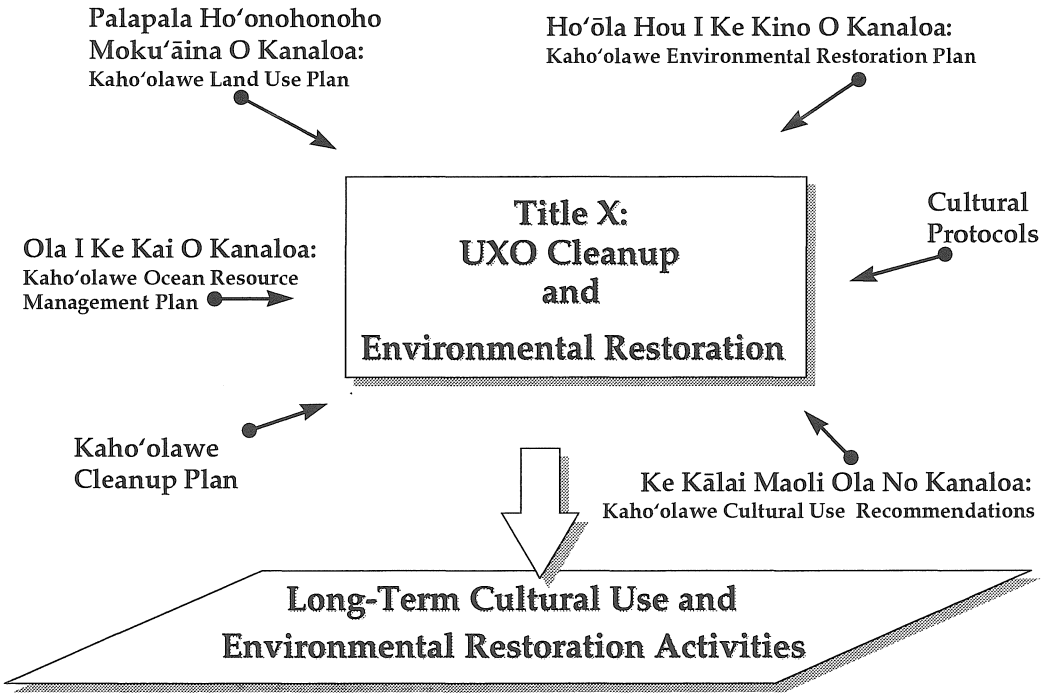
Chapter 1

Introduction

Reestablishing Kaho'olawe's vegetative cover is key to its environmental stabilization. Forests and shrublands of native plants and other biota will eventually clothe its slopes and valleys. As the first steps to achieve this vision, the Kaho'olawe Island Reserve Commission (KIRC) offers this document, *Ho'ōla Hou I Ke Kino O Kanaloa: Kaho'olawe Environmental Restoration Plan*. It presents a comprehensive strategy for healing the kino of Kanaloa, the island of Kaho'olawe.

Ho'ōla Hou I Ke Kino O Kanaloa constitutes the fourth major planning and policy document developed by KIRC. This plan strives to create a landscape worthy of the vision set out in *Palapala Ho'onohonoho Moku'āina O Kanaloa* (Kaho'olawe Use Plan). In conjunction with *Ola I Ke Kai O Kanaloa* (Kaho'olawe Ocean Resource Management Plan), it recognizes the interconnectedness of the land with the sea. This plan supports the native

figure 1.1 – **Interrelationship of Plans to the Cleanup and Restoration**



Hawaiian management approach and the cultural uses contained in *Ke Kālai Maoli Ola No Kanaloa* (Kaho'olawe Cultural Use Recommendations).

When the Title X unexploded ordnance clearance ends in 2003, the US Navy will no longer maintain a presence on the island. At that time, the Kaho'olawe Island Reserve Commission (KIRC) will institute an access policy for reasonably safe, meaningful use of the island. What this policy will be, in terms of activities, residency, improvements, opportunities, and restrictions is not yet defined. KIRC will develop a broader strategy and program plan to address these issues.

Audience

Ho'ōla Hou I Ke Kino O Kanaloa has been written for four distinct audiences: the Kaho'olawe Island Reserve Commission; the United States Navy; the people of Hawai'i; and future generations. A clear purpose has been defined in this plan for each audience.

TO ASSIST KAHO'OLAWE ISLAND RESERVE COMMISSIONERS IN HEALING KANALOA. Achieving KIRC's vision for Kaho'olawe will require an incremental restoration strategy working in concert with the natural healing of the island. This document is intended to serve as a blueprint for a restoration process.

TO GUIDE THE UNITED STATES NAVY IN COORDINATING CLEANUP AND RESTORATION ACTIVITIES. The larger goal of the United States Navy's unexploded ordnance clearance is to facilitate Kaho'olawe's restoration and meaningful use. Not only must the goals and the vision of KIRC and the Navy complement each other, but also the two must work cooperatively throughout the Title X cleanup.

TO PROVIDE INFORMATION TO THE COMMUNITY ABOUT KAHO'OLAWE AND OPPORTUNITIES FOR PARTICIPATION. The environmental restoration of Kaho'olawe began with a decades-long, grassroots effort to stop the bombing and to restore life to the island. The vision shared here owes its origin to the people of Hawai'i. This plan recognizes that only with broad-based support and community involvement can the healing of Kanaloa succeed.

TO FURNISH A LONG-TERM STRATEGY FOR FUTURE GENERATIONS. The restoration of Kaho'olawe requires the laulima and kōkua of generations to heal the problems of desertification, catastrophic erosion, and infestation by exotic pests. As such, this plan provides a long-term vision, and near-term restoration activities.

Environmental Restoration Planning Process

The United States Congress passed Title X (Public Law 103-139, 107 STAT. 1418, 1479-1484) in 1993. Title X returns Kaho'olawe to the State of Hawai'i and authorizes $400 million over a ten-year period to pay for unexploded ordnance clearance and environmental restoration of the island by the US Navy and the State of Hawai'i.

Figure 1.2
Kaho'olawe Environmental Restoration Planning Process

Phase I: Preparation for the Navy's Request for Proposals
- Erosion Abatement Workshop
- *Erosion Control Recommendations for Inclusion in the Navy's Kaho'olawe Omnibus Cleanup Request for Proposals*
- *Lessons Learned from Past Restoration Efforts*

Phase II: Technical Studies and Strategies
- Indigenous Knowledge
- Restoration of Vegetation on Kaho'olawe
- Erosion Mitigation and Control
- Faunal Restoration
- Water Study Review and Calculation

Phase III: Plan Production and Public Review
- Revegetation Workshop
- Integration Workshop
- Community Involvement Workshop
- Production of Draft
- Statewide Public Review
- Finalization of Plan

Hawaii Revised Statutes (HRS) Chapter 6K established the Kaho'olawe Island Reserve Commission (KIRC) in 1994. KIRC is a seven-member state commission administratively attached to the Department of Land and Natural Resources. It has special management area and land use authority for Kaho'olawe and coastal waters out to two miles around the island. The Kaho'olawe Island Reserve Commission also has the responsibility for planning the restoration of the island and determining its future use, until such time as a Native Hawaiian sovereign entity is recognized by the United States Congress and the State of Hawai'i. KIRC, with assistance from the University of Hawaii's Social Science Research Institute, has developed this plan.

Steering and Technical Advisory Committees

KIRC convened two committees to assist its staff and the Social Science Research Institute's project team in developing the plan. The Steering Committee and the Technical Advisory Committee met throughout the course of this planning process and provided invaluable guidance.

Phase I

KIRC held a workshop in May 1996 to develop erosion control recommendations for the Navy's cleanup request for proposals. Participants identified opportunities for restoration during the cleanup process and cleanup procedures to minimize erosion and further environmental degradation on the island. The final report was forwarded to the US Navy. During this phase of the planning process, the Kaho'olawe Island Reserve Commission sponsored a study compiling knowledge gained from prior restoration efforts on Kaho'olawe, entitled *Lessons Learned: Kaho'olawe Restoration Efforts Prior to 1996*.

Phase II

KIRC and the Technical Advisory Committee used the preliminary results from *Lessons Learned* to develop a request for proposals for a series of technical options studies. Strategy reports, based on these studies, were written on indigenous knowledge, revegetation, erosion control, faunal restoration, and water. To integrate the results of the technical studies into a coherent restoration plan, two workshops were held: a revegetation workshop in March 1997 and an integration workshop in July 1997. This plan is the culmination of the technical papers and these workshops.

A Community Involvement Workshop was held in late July 1997 to solicit ideas on how to best involve the people of Hawai'i in the restoration process. An open invitation was extended to the community at-large, emphasizing Hawaiian, youth, environmental, and civic organizations. The nearly 100 community participants provided excellent and useful ideas. Their demonstrated enthusiasm and high level of interest will help support the successful restoration of Kaho'olawe.

Phase III

KIRC released the draft *Ho'ōla Hou I Ke Kino O Kanaloa* for public comment in September 1997 and held public information meetings on O'ahu, Maui, Kaua'i, Moloka'i, Lāna'i, and Hawai'i in October 1997. KIRC reviewed the results of the public meetings. KIRC and SSRI project staff finalized this plan in May 1998.

photograph 1.1: **Oawawahie** (S. Enomoto)

Chapter 2

Principles of Environmental Restoration

The environment of Kaho'olawe, the kino of Kanaloa, is not static. Rather, Kaho'olawe is a living, dynamic, changing system, more complex than our limited understanding can fully comprehend. Intuitive insight, coupled with a sense of humility and an ability to remain flexible, provide an effective approach to healing the island. The Kaho'olawe Island Reserve Commission has identified several operating principles to guide the implementation of the restoration program.

'Ike Pāpālua

Translated as "being guided by a vision with deeper insight into the quality of the land and its surrounding resources," 'ike pāpālua acknowledges the inspiration and insight gained through observation and informed from spiritual awareness.

Traditional Ecological Knowledge

In addition to a well-developed intuitive sense, native Hawaiian kūpuna have a highly advanced understanding of ecosystem dynamics. Restoration of Kaho'olawe provides an opportunity to rekindle traditional planting and land management practices. KIRC will make a conscious effort to maintain a cultural approach and focus to achieve the environmental and spiritual healing of Kanaloa.

Systematic and Connective Approach

It is not enough to slow erosion, increase soil moisture, eradicate mammalian predators, and encourage native flora growth. Successful restoration depends on understanding dynamic ecosystem interactions among plants, animals, soils, climate, and other natural processes. For example, recognizing the interdependence between soil microbes, plants, and faunal species within an ecosystem will improve revegetation efforts.

Ecosystem Succession

Establishing diverse native communities will require time and patience. Therefore, KIRC will employ an incremental, successional approach to complement naturally occurring changes in plant composition within native ecosystems. For instance, incremental steps may convert a barren, eroded landscape to an alien-dominated grassland, to an ʻaʻaliʻi shrubland, and eventually result in the natural evolution of portions of the shrubland into a koaiʻa forest.

Strategic Restoration

Technical and economic constraints make it unrealistic to locate erosion control structures and install outplantings across the entire island. Small sections will be actively treated. This, in turn, will assist the natural recovery process to "fill in" larger areas. In other words, over five acres only one acre may be treated, but these treatments will be strategically placed to facilitate restoration of the full acreage to recover through natural processes.

Observe and Listen to the ʻĀina

Careful observation of the environment, the climate, and natural processes on Kahoʻolawe will teach restoration managers how to heal the island. Knowledge of the impacts of hot, dry winds, the directions from which they come, and in what times of year, will help to determine a revegetation strategy to take advantage of the moisture-bearing winds. Listening to the land means planting will be done during the wet season, and road construction will commence at the beginning of the dry.

Community and Native Hawaiian Involvement

The environmental restoration of Kaho'olawe provides the people of Hawai'i with an opportunity to learn and practice stewardship using the best of traditional and modern knowledge. Strong community involvement from members of the public, community groups, and the Protect Kaho'olawe 'Ohana will invigorate and broaden the healing of Kanaloa.

Cooperation with the US Navy

The restoration of Kaho'olawe will be a long-term process and decisions made today can foreclose or enhance opportunities in the future. The Kaho'olawe Island Reserve Commission and the US Navy must cooperate to ensure infrastructure development and other activities of the cleanup will support the long-term restoration and use of the island.

Integrated Research and Action

Much more must be learned about native plant propagation and survival, control of exotic species, ecosystem succession, erosion control, and native fauna. Therefore, the restoration will implement and evaluate techniques on a small-scale, maintain a monitoring program to determine successes and needed improvements, and apply those lessons to the healing of Kanaloa.

Chapter 3

Natural History, Present Challenges, and Future Vision

Natural History of Kaho'olawe

Kaho'olawe's current environmental character emerges from the impact of its human history upon the landscape.

Ancient Period

Hawaiians began to live on Kaho'olawe about 1000 AD. Settlement and expansion into the mauka areas peaked in the 1600s. Parts of the original forest were converted to dryland agriculture, growing food crops such as 'uala, uhi, kō, kalo, and mai'a. To successfully propagate these crops, Hawaiians applied their keen understanding of wind and water cycles, knowledge of the environment, and recognition of their interdependency with the 'āina.

Severe loss of vegetation and soil did not begin until after the introduction of goats at the end of the eighteenth century. Upon leaving Maui in March 1793, Captain George Vancouver presented goats to Kahekili as a farewell gift. The Maui leader sent the goats to Kaho'olawe.

photograph 3.1: **Lua Keālialalo** (S. Enomoto)

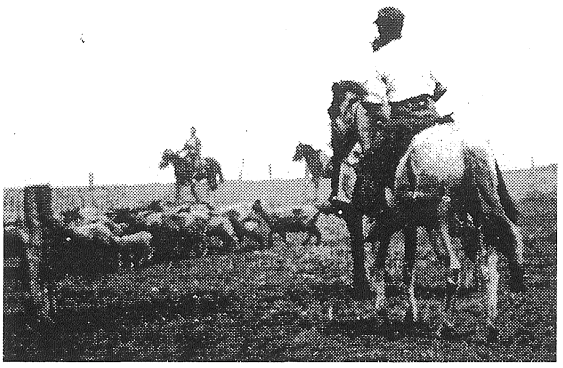
Water was never abundant on Kaho'olawe. In 1834 Reverend William Richards observed island residents harvesting dew from oiled kapa for drinking water. Prior to the early 1900s, Lua Makika, Lua Keālialuna, and Lua Keālialalo, as well as

depressions within stream beds, acted as natural water catchment during the rainy season and continued to hold some water for several months.

Nineteenth century forestry reports mentioned a "dense forest" at the top of Kaho'olawe and a cloud bridge connecting the island to the slopes of Haleakalā. Kūpuna recalled naulu rains sometimes occurring when the tradewinds blew. These showers accounted for some of the dry season rainfall.

Ranching Era

photograph 3.2: **Kaho'olawe Ranchers**
(Bishop Museum)



Robert Wyllie brought sheep ranching to Kaho'olawe in the nineteenth century. Successive (sub)leases over the years continued the ranching tradition. Historic accounts of the 1860s indicate that goat-induced wind and water erosion had already started. Of the island's forests, only 'akoko had survived. Cattle arrived in 1880. Overgrazing by large herds of goats, sheep, and cattle led to significant wind and gully erosion within a few years. Ranchers introduced kiawe in the late 1880s in an effort to check erosion. By 1890, ranchers recorded 9,000 goats, 12,000 sheep, and 900 cattle.

During the 1909 legislative session, Hawai'i's territorial House of Representatives passed a resolution stating, "the Island of Kaho'olawe should not be leased upon the termination of the existing lease, but that every effort should be made by the proper authorities for the killing of all animal life...and for the improvement and restoration of the plant life" (HCR 19). Within a year, territorial Governor Walter Frear designated Kaho'olawe as a forest reserve (1910). Despite the short period of reserve status, territorial officials made limited progress toward their restoration goals: reduction of the sheep and goat population and revegetation of the island (albeit with 'spineless' cactus, ironwood and grape trees, Australian saltbush, and other alien species). They also collected the first rainfall data for the island.

In 1918, Kaho'olawe was again leased to cattle ranchers, with the stipulation that goat eradication and revegetation efforts continue. They removed approximately 13,000 goats and killed many more. They also

dispersed hundreds of pounds of Australian saltbush, natal redtop, and pili seeds. Tree seedlings were planted near Lua Makika and Pu'u Moa'ulaiki, alongside a double row of eucalyptus as a windbreak. Other species planted during the rainy season included māmane, 'iliahi, kamani, kukui, 'ōhi'a lehua, 'ōhi'a 'ai, ma'o, paka, olonā, and wauke. These plantings provided excellent ground cover and minimized wind and soil erosion. The ranchers also built a water collection system based on cisterns and reservoirs; a cistern still remains intact above Honokanai'a. By 1920 wells used by the ranch were too brackish for use.

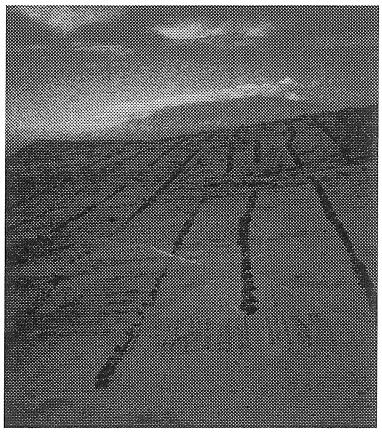
Military Period

Seven months before the Japanese bombed Pearl Harbor, the US military negotiated an agreement to use a portion of Kaho'olawe as a live ordnance range. After December 7th, 1941, the military declared martial law and seized the entire island. Restoration work ceased. For nearly fifty years, the military used the island as a practice target range. A 1953 Executive Order formally transferred the island to the Navy and required them to eradicate the goats and sheep. For most of the military period, however, the goat population was high and, at times, reached 50,000. Beginning in the 1970s, the Navy permitted several agencies and organizations to implement conservation work on the island.

The United States Forest Service conducted a series of vegetation trials in the early 1970s to identify tree, shrub, and grass species most adaptable to the island's now harsh environment. Because of goats and poor soil moisture, most of the species planted died. Only three, wiliwili, ombu, and 'a'ali'i, survived. Sometime during this period, foresters from the state's Division of Forestry and Wildlife introduced buffelgrass by spreading seeds from a helicopter.

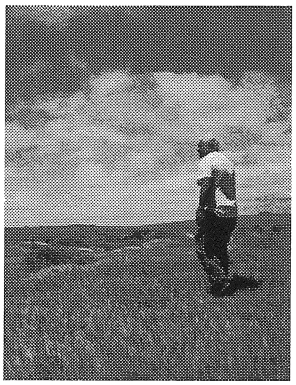
In 1976, Protect Kaho'olawe 'Ohana (PKO) began its protest and litigation movement over the damaging practices of military use and called for Kaho'olawe's return to the Hawaiian people. As a result of these efforts, the US Navy signed a Consent Decree with PKO in 1980. A Memorandum of Understanding (MOU) with the State of Hawai'i soon followed. This MOU required the Navy to begin soil conservation, revegetation, and goat eradication programs on Kaho'olawe.

photograph 3.3: **DLNR Windbreak Project**
(A. Chun Smith)



The state's Division of Forestry and Wildlife, in cooperation with the Navy, embarked on a fourteen year project (1979-1993) to mitigate soil erosion by planting tamarisk and ironwood windbreaks. Feral goats stripped the bark from ironwood trees, making tamarisk the principal species. After the conveyance of Kaho'olawe back to the State of Hawai'i, the Navy withdrew its support from the project. By that time, foresters had planted 800 acres with the trees. Today, they form windbreaks along portions of the eastern end of the island, reducing erosion and evaporation between rows of trees.

photograph 3.4: **NHPS Project**
(K. Fairbanks)



The Native Hawaiian Plant Society planted native Hawaiian species on Kaho'olawe from 1985 until 1989. Project coordinators selected the most degraded and windswept areas of the island to demonstrate native Hawaiian plants could revegetate the island, under the harshest conditions. 'Aki'aki, 'emola, and 'a'ali'i worked best.

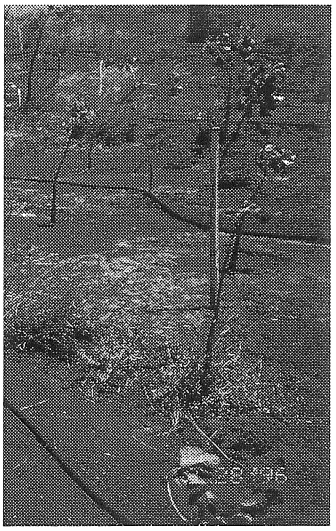
From 1987 to 1991, the US Army Corps of Engineers Construction Engineering Research Laboratory (CERL) and the Pacific Division, Naval Facilities Engineering Command (PACDIV) studied, designed, implemented, and evaluated a watershed rehabilitation plan. This project was intended to develop effective and economical methods for land reclamation and revegetation on Kaho'olawe without supplemental watering. The project team planted buffelgrass, Bermuda grass, weeping lovegrass, annual ryegrass, milo, sorghum, and wheat.

The Protect Kaho'olawe 'Ohana (PKO) made numerous coastal plantings with varying success, starting with its earliest occupations in 1976. In 1987, PKO successfully lobbied the state's Department of Land and Natural Resources (DLNR) to do a study of the island's water resources. As part of the study, PKO entered into a cooperative agreement with the United States Geological Service to measure stream flow and basal groundwater, to conduct electrical resistivity tests, and to analyze the island's watersheds, surface runoff, and erosion problems. Soil control structures (*e.g.*, checkdams) and vegetation were investigated as a means to reduce erosion and heal the island. PKO successfully secured a

$250,000 grant-in-aid from the Hawai'i State Legislature in 1989, and has continued with small-scale water catchment, erosion control, and revegetation projects in the Hakioawa watershed.

The Nitrogen-Fixing Tropical Agricultural Legumes (NiFTAL) Project studied microbial and mineral constraints to reestablishing wiliwili in the eroded soils on Kaho'olawe. The project ran between 1989 and 1991.

photograph 3.5: **NiFTAL Project** (A. Chun Smith)



Although numerous attempts had been made to eliminate goats from the island, none were successful until the Navy began a concerted effort in 1986. Effectively eliminated in 1990, the final "Judas goats" were removed in 1993. Goat eradication may be the single greatest factor contributing to the eventual recovery of vegetation on the island.

Challenges and Opportunities

Current environmental conditions on Kaho'olawe pose tremendous challenges to the implementation of this plan. These ecological constraints are further amplified by logistical and financial challenges.

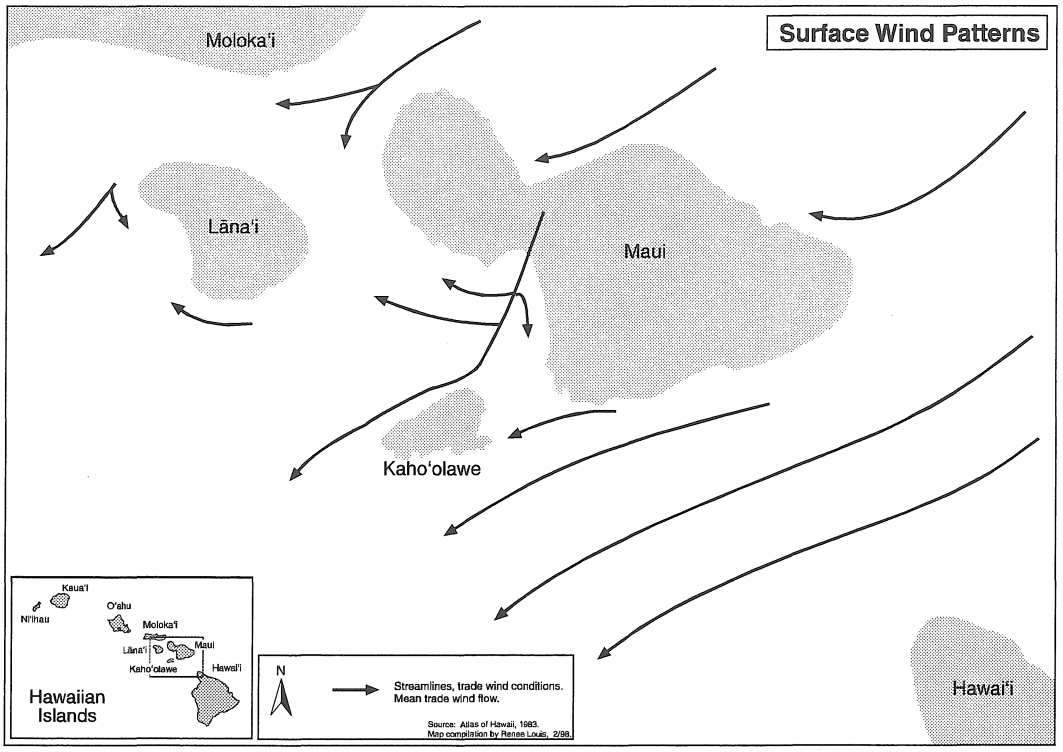
Biological and Ecological Challenges

The physical environment of Kaho'olawe is severely degraded. Erosion has removed topsoil from much of the island. During heavy rains, water rushes down steep slopes, cutting deep gullies and carrying large amounts of soil into the sea. An estimated 1,880,000 tons of soil continues to be lost each year as a result of erosion.

Approximately twenty-five inches of rain falls annually on Kaho'olawe's summits, and less than ten inches along the coast. In "normal" years, the island receives very little precipitation during the dry season, March through October. Much of the rainfall on Kaho'olawe comes in short, heavy downpours and, because of the lack of vegetation and compacted soils, very little soaks into the ground. Periodically, the island receives more rainfall than normal, but the lack of complete rainfall record makes wet years difficult to predict.

Kaho'olawe lies at the apex of a natural wind tunnel, with Haleakalā and the peaks of the Island of Hawai'i forming the base. Northeast trade winds blow most of the year. These strong winds blow loose soil up from the eastern coast, across the island, and deposit it on the western end of Kaho'olawe or in the ocean. Winds also "sandblast" plants in exposed areas.

map 3.1



In mauka areas, a hard, polished, burnt orange-colored crust covers the landscape. These "hardpan" soils lack nutrients, moisture, and microbes necessary for plants to survive. In pockets of loose, eroded soil, vegetation emerges, but alien species dominate – partly because of the limited number of native plants on the island.

Most of the plants on Kaho'olawe are aggressive, hardy, alien species. Natal redtop, buffelgrass, and kiawe dominate most vegetated areas, competing with native plants and posing a serious fire hazard. The few native plants that remain provide a limited seed supply for natural regeneration.

Feral cats and house mice also pose a threat to restoration efforts. Cats threaten native seabirds, and along with loss of habitat, are probably

responsible for the absence of a variety of birds on Kaho'olawe. House mice eat seeds and other plant matter.

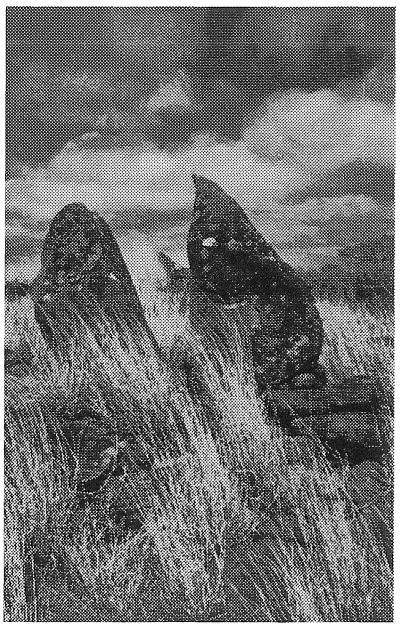
Logistical and Financial Challenges

Kaho'olawe was used as a military target for over 50 years. Nearly every type of conventional ordnance used by the US military and its allies since World War II has been dropped or fired on Kaho'olawe. Some ordnance remains resting on the island's surface or buried in the ground. Other items are washed down gullies and still other unexploded ordnance rest beneath the waters offshore. The possibility of unintentionally exploding these unstable, aging UXO is real.

Access to Kaho'olawe is restricted because of the danger posed by unexploded ordnance and the associated liability. Currently, people must limit their movements on the island, unless accompanied by an explosive ordnance disposal (EOD) technician. The general shortage of EOD technicians makes it difficult to facilitate access. Restrictions on access have directly contributed to the failure rate of past restoration efforts, because regular care of native plants has not always been possible.

It is not certain how much land can be cleared of UXO to allow ground-disturbing activities, such as tilling, planting, and digging. Moreover, the amount that will eventually be appropriated for cleanup and restoration is unknown. Given the high cost of clearance, there are probably insufficient funds available for both subsurface ordnance clearance and erosion control of the entire hardpan. Therefore, the Kaho'olawe Island Reserve Commission's erosion control strategy requires the close cooperation of the Navy.

photograph 3.6: **Pu'u Mōiwi Shrine** (S. Enomoto)



Numerous archaeological sites exist across the hardpan with a high concentration near the summit. Kaho'olawe's placement on the National Register for Historic Places generates a host of archeological considerations for both the cleanup and restoration. Besides requiring an on-site archeologist, this status brings in another layer of government bureaucracy. Numerous archaeological sites exist across the hardpan with a high concentration near the summit.

Opportunities

Kaho'olawe presents many unique opportunities. Never before has a restoration attempt been made on such a large-scale in Hawai'i. Lessons from Kaho'olawe may be applied to other dryland ecosystems locally and internationally. The restoration of Kaho'olawe places traditional practices and cultural protocols at the forefront of ecological recovery efforts. The numerous archaeological and cultural sites provide an opportunity to integrate site stabilization and native revegetation. Environmental restoration of Kaho'olawe allows KIRC to model native Hawaiian cultural and spiritual approaches to land management and care.

Kaho'olawe provides a tremendous opportunity for public agencies and private organizations to join in partnership with KIRC to develop and learn from methods for controlling erosion, eradicating plant and animal pests, and reestablishing native ecosystems. The relative isolation of, and limited access to, Kaho'olawe has protected the island from a number of plant pathogens and alien pests.

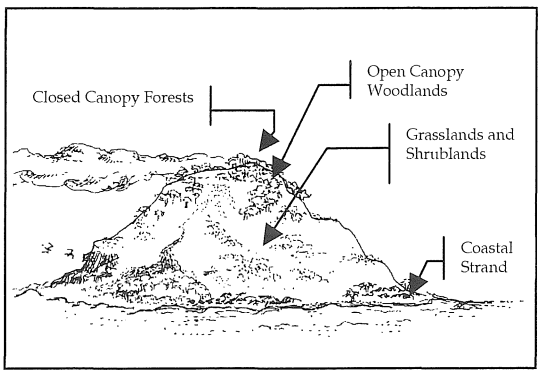
Many people, from government, non-profit organizations, Hawaiian and community groups, private businesses to individuals, care deeply about the island and share KIRC's vision for its future. Environmental restoration offers an opportunity for contribution and participation by the broader community in the healing of Kanaloa.

Envisioning a Restored Kaho'olawe

> *The kino of Kanaloa is restored. Forests and shrublands of native plants and other biota clothe its slopes and valleys. Pristine ocean waters and healthy reef ecosystems are the foundation that supports and surrounds the island.*
>
> *Nā po'e Hawai'i care for the land in a manner which recognizes the island and ocean of Kanaloa as a living spiritual entity. Kanaloa is a pu'uhonua and wahi pana where Native Hawaiian cultural practices flourish.*
>
> *The piko of Kanaloa is the crossroads of past and future generations from which the Native Hawaiian lifestyle spreads throughout the islands.*
>
> – Vision Statement, Kaho'olawe Island Reserve Commission

As the vision statement unfolds, native-dominated ecosystems blanket Kaho'olawe. Its oceans and reefs thrive, filled with aquatic life. The people of Hawai'i respectfully manage the island. Consecrated once more, indigenous cultural and religious sites have spiritually renewed Kaho'olawe. It is this vision which *Ho'ōla Hou I Ke Kino O Kanaloa* strives to develop and support.

sketch 3.1: **A Native Ecosystem Vision**



Imagine one hundred years from now, Kaho'olawe has restored, native mesic forests, shrub- and grasslands, its coastal waters shining and clear; the island a beacon for Hawaiian culture and practice. Picture Kaho'olawe restored with flourishing native biota in each of its zones.

Closed Canopy Forests

Closed canopy, dry and mesic forests cap the summits of the island. A mixture of Maui Nui lowland plant communities – from koai'a, 'uluhe, or halapepe to those marked by 'ōhia, olopua, wiliwili, or lama – reflect the physical and spiritual healing of Kanaloa. Here, a pair of 'amakihi has hatched. A kahu sets a kapu on the area so the birds will remain undisturbed until the fledglings are sure to survive.

Lush foliage catches the rain and fog, replenishing the island's aquifers. The vegetation provides secure nesting sites for native birds. Numerous cultural and religious sites dot upland areas. At Pu'u Moa'ulaiki students train in astronomy and ocean navigation, learning to watch the positions of the stars, the clouds, and ocean currents.

Open Canopy Woodlands

Traveling makai from Pu'u Moa'ulaiki, open canopy woodlands thrive. As an intermediary between the forests above and the grass-lands and shrublands below, its communities reflect a similar species composition. Its ecosystems encompass forest communities such as halapepe, koai'a, lama, olopua, or wiliwili; grass-lands and shrublands of 'akoko, 'a'ali'i, ko'oko'olau, 'ūlei, 'ilima, ma'o, or pili.

A steady rain comes to Lua Makika, feeding a network of water catchments across the island and refreshing the seasonal wetlands where kōloa and ae'o nest. At kahua kauhale, people pull mulch away in the food gardens and from the newest tree plantings, allowing the land to drink its fill. When the rain is pau, their work will be to cover the plants again so the soil will stay cool and moist for the rest of the week.

In upland gardens, men tend 'uala beds as they begin to mound. Women gather lauhala from a grove dedicated to the kūpuna who were part of the struggle for Kaho'olawe's return. They begin the process of mat making for the hale o papa and the men's heiau, and the preparation of roofing material to patch the kahua ho'omoana. The wauke gives its bark for kapa. 'Ulu begins to lower its branches to the ground from the weight of its fruit.

Grasslands and Shrublands

Further down, lay vast expanses of dry grasslands and shrublands. Once dominated by natal redtop, buffelgrass, kiawe, and other alien species, these intermediary areas now primarily pili, naio, or kāwelu, and communities similar to that of open canopy woodlands. There are now 'akoko, 'a'ali'i, ko'oko'olau, 'ūlei, 'ilima and ma'o growing among halapepe, koai'a, lama, olopua and wiliwili. A group of nēnē slowly moves off the trail where they have been feeding on the seed of pili and other native grasses. In the few remaining acres of hardpan, the long arms of 'uhaloa continue to weave the land back together. Even though the cleanup happened one hundred years ago, bombs still rise like stones to the surface. It is the 'āina continuing to cleanse itself. At the mouth of Ahupū Gulch, a fourth generation team of skilled, Hawaiian EOD removes and disarms an old shell.

Coastal Strand

An abundance of native communities – 'aki'aki, 'ilima, ma'o, 'ākulikuli, naupaka kahakai, hinahina, naio, or pōhuehue – stabilize the sand dunes and create healthy coastal ecosystems. Gardens of hala, milo, niu, and kou surround the kahua kauhale. Lā'au lapa'au are planted to replenish the island's pharmacy. Residents and visitors fish for ulua, 'āweoweo, uhu, palani, pāpio, and kūmū. They gather limu kala, 'opihi, and limu 'ele'ele in the tidal pools. 'Īlio holo i ka uaua relax on the sand. Honu saunter slowly into the ocean. The shoreline teams with migratory birds, such as the hunakai, 'akē'akē, kōlea, kioea, and 'ūlili. 'Iwa nests adorn

the naupaka kahakai. Heiau have been (re)dedicated, and provide the focus for spiritual life on Kaho'olawe.

A wa'a crew bringing a new group of haumana pulls its sails in; calls out for the response to welcome them to shore.

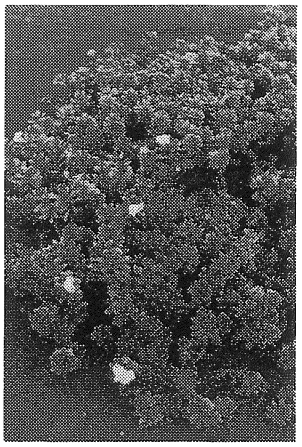
photograph 3.7: **Puu Ka ohe (?)** (K. Fairbanks)

Chapter 4

Restoring Kaho'olawe

The healing of Kanaloa is a physical and spiritual renewal manifested through cultural ceremonies and practices, and environmental activities. This comprehensive restoration of Kaho'olawe requires the regeneration of soil, native plant and animal life, and the natural water system. Strategies addressing erosion control, botanical and faunal restoration, and enhancement of the natural water system are introduced in this plan.

photograph 4.1: **Hinahina**
(P. Levin)



Erosion Control

Through soil stabilization and revegetation, KIRC will work to reduce the loss of soil currently bleeding into the sea. Besides destabilizing the land, water and wind erosion threaten religious sites, use areas, and coastal fisheries. Five types of eroded landscapes have emerged on Kaho'olawe

- undissected hardpan,
- dissected hardpan,
- rilled plateau,
- boulder fields with saprolite, and
- deep gullies and headcuts.

Each will require a different erosion control strategy. Initial efforts will emphasize:

- culturally and ecologically important sites;
- mauka areas where erosion begins;
- the eastern third of the island, and
- all ground disturbance associated with ordnance cleanup.

Erosion and Runoff Control Standards, jointly developed by KIRC and the Navy, will mitigate UXO cleanup efforts. Erosion control will receive greatest emphasis during initial revegetation efforts on Kaho'olawe.

Hardy, fast-growing, sun-tolerant, drought- and wind-resistant plant species which enhance soil development and retention will be employed first.

Botanical Restoration

Through botanical restoration, KIRC will reestablish native plant communities in eroded and alien-dominant landscapes, and expand the remaining pockets of native vegetation (kīpuka). It will take generations, however, for the island's ecosystem to stabilize and revert to native ecosystems. Kaho'olawe's eroded landscapes provide a good opportunity to establish native plants with fewer obstacles from alien species. Alien-dominated landscapes, such as kiawe-buffelgrass savanna, have served to hold the soil in some areas of the island, but create formidable competition to the reestablishment of native ecosystems. Botanical restoration will also focus on the expansion and enhancement of kīpuka which still maintain native plants and seed banks. The establishment of gardens at the kahua kauhale will provide another avenue for botanical restoration, especially for lā'au lapa'au plants.

Faunal Restoration

Faunal restoration entails reintroducing native species and recreating the habitat that supports and sustains them. Initially, faunal restoration efforts will be limited to selected surveys and monitoring to determine which species currently live on Kaho'olawe and the size of the populations. Botanical restoration will receive primary emphasis to begin regenerating habitats to support native fauna. Since it is not clear how the presence of pests impedes erosion control, revegetation, and faunal restoration efforts, it is currently not known what eradication and reintroduction methods will be technically and financially feasible.

Enhancing the Natural Water System

Restoring the island's natural water system is key to sustaining life on Kaho'olawe. This system includes rain, but also stays hidden. It lies in the moisture in the ground, in plants, and in dew from the night air. It rests in the lee and the shade beneath rocks. It hangs in the clouds across

the channel on the slopes of Haleakalā, and the clouds that brush across the island without rain. It is present in the tradewinds and the sudden naulu rains.

KIRC will seek to heal the island and its natural water system through ceremonies and prayers to increase rainfall and restore the cloud bridge between Maui and Kaho'olawe. The Lonoikamakahiki ritual has been reestablished since 1982. Rain ko'a or heiau ho'oulu ua will be established to attract rain at appropriate points, particularly along the rim of Lua Makika. Puhi mai, e Kanaloa, nā mea maika'i no ke ola hou o kou kino!

KIRC will focus on restoration methods that enhance and strengthen the island's ability to capture and conserve the "invisible" water in plants, in the soil, and from the air. Planting and soil erosion methods will be used to husband natural water resources, enhance water capture and retention, and increase plant survival. These techniques include:

- planting using the pattern of the landscape;
- tree "mats" as small-scale catchment pans and to guide water to tree roots;
- swales and riplines;
- windbreaks;
- craters and depressions;
- road catchment; shade; and
- appropriate timing for each treatment.

As a healthy native forest is reestablished at the summit, the natural water system will begin to be restored sufficiently to sustain ecological needs and to recharge the island's aquifers.

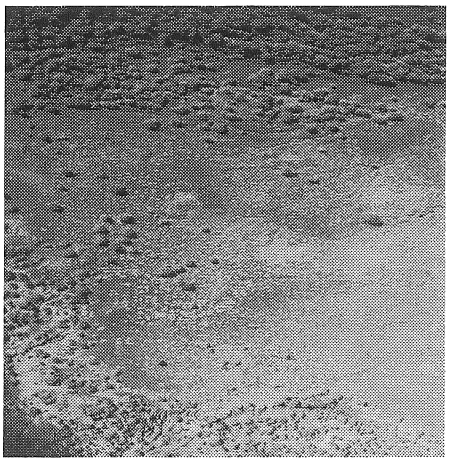
Landscape Types

Eight landscape types are currently found on the island. Each presents a different problem and has unique requirements for restoration. A site-specific approach, guided by generalized treatments outlined in this plan, will be applied.

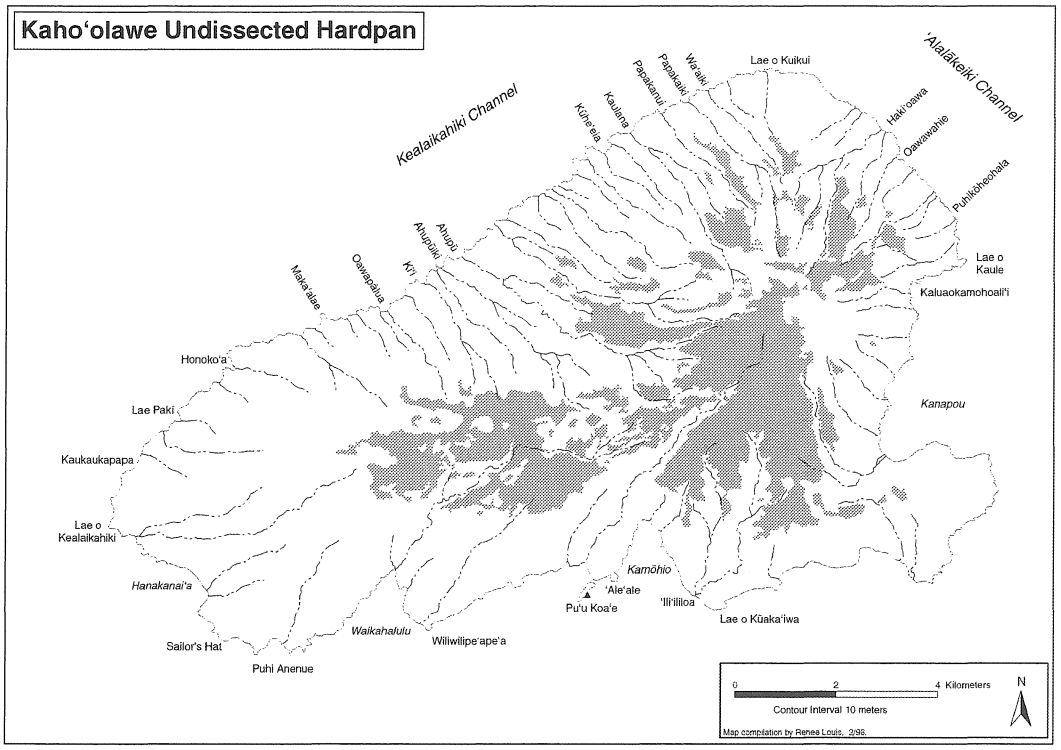
Undissected Hardpan

Primarily characterized by sheet erosion from high levels of water runoff, the undissected hardpan occupies almost 5,500 acres in the center of Kaho'olawe. The surface crust must be broken to allow seed germination and to increase water infiltration. In depressions and areas naturally protected from wind, revegetation is occurring. It is unlikely, however, that vast areas will revegetate naturally without controlling wind and water erosion.

photograph 4.2: **Undissected Hardpan between Pu'u Mōiwi and Lua Keālialalo** (S. Enomoto)



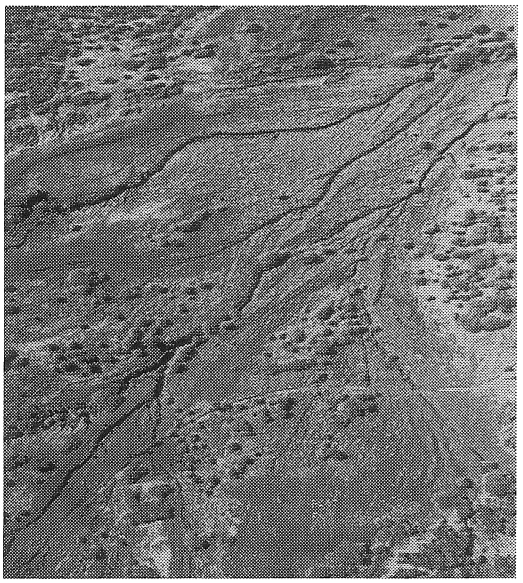
map 4.1



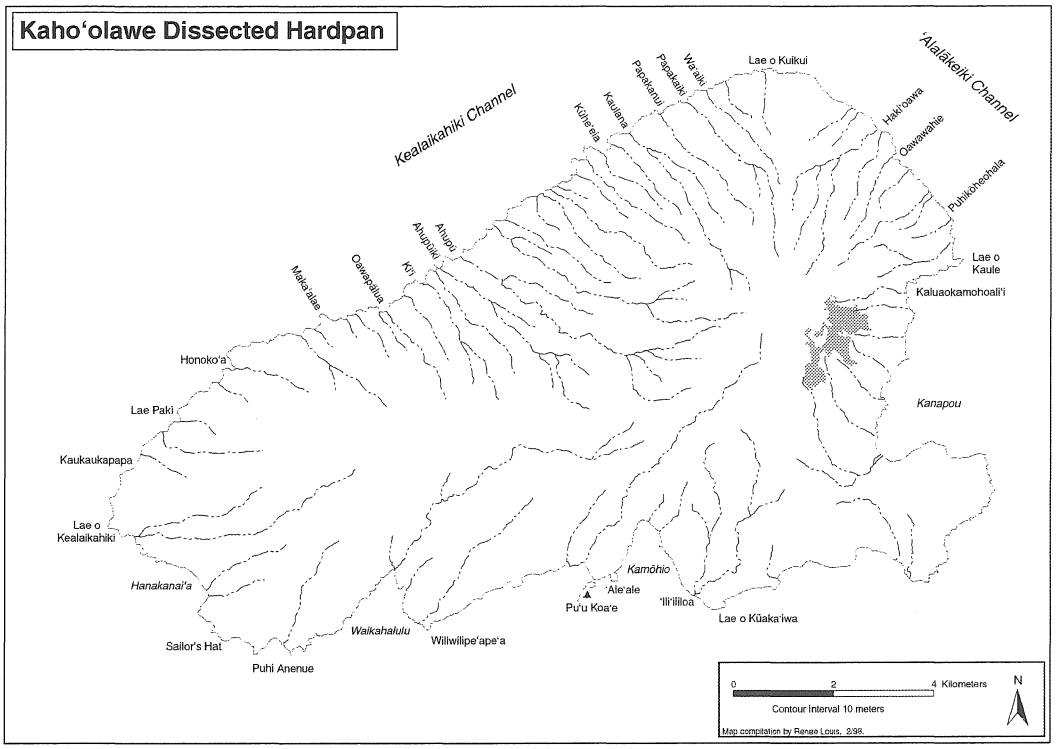
Dissected Hardpan

Mainly located on the most windswept eastern and southeastern slopes of Lua Makika, a large number of gullies (roughly one to six feet deep) crisscross roughly 225 acres of dissected hardpan. During heavy rains these gullies become flash flood channels. Some sediment pockets have persisted long enough for small shrubs and grasses to grow.

Photograph 4.3: **Dissected Hardpan South of Pu'u Moa'ula** (S. Enomoto)



map 4.2

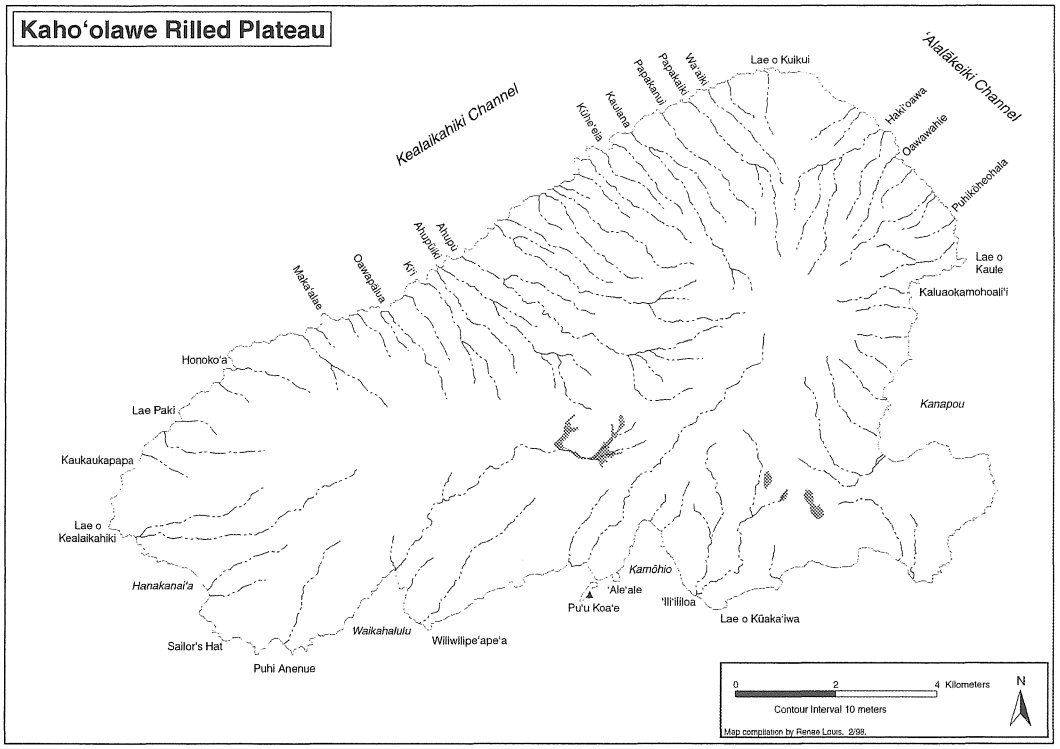


Rilled Plateau

The 105 acres of rilled plateau eroded landscape occurs where runoff exits steeper knolls and pu'u (*e.g.*, southern side of Pu'u Mōiwi).

photograph 4.4: **Rilled Plateau on the Outer Rim of Lua Makika** (P. Levin)

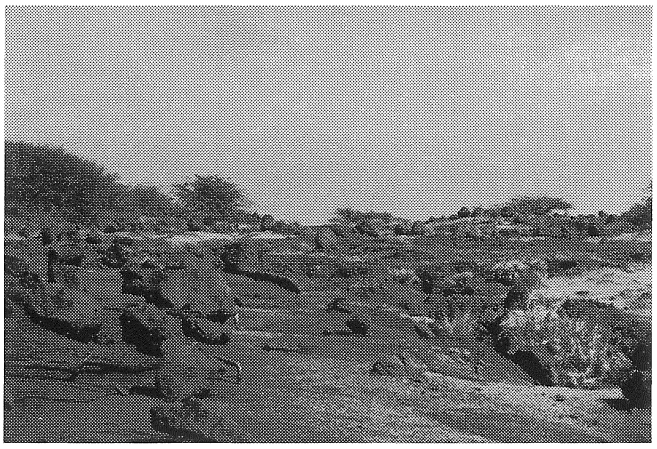
map 4.3



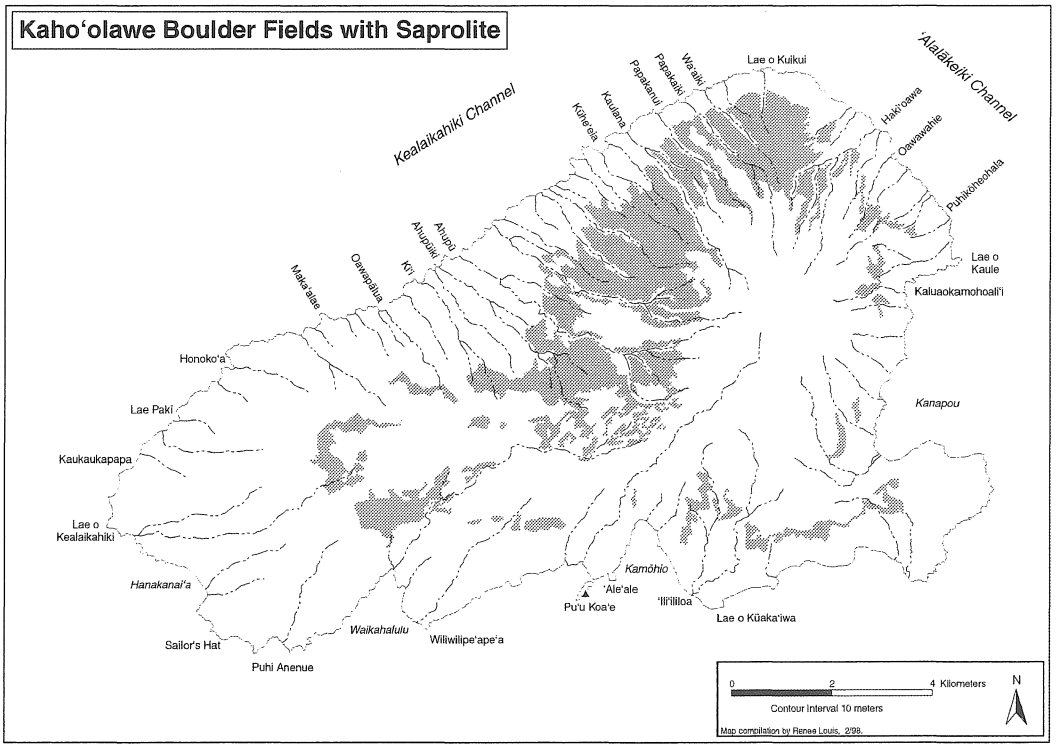
Boulder Fields with Saprolite

Soils that have eroded down to the underlying, weathered lava flows characterize boulder fields with saprolite. Resistant portions of the old lava flows have persisted as rounded rock fragments varying greatly in size across this eroded landscape's 4,355 acres. The upper end of the boulder fields tends to intersect the rilled plateau, the lower part joins either gullied lands or the kiawe and buffelgrass savanna.

photograph 4.5: **Boulder Fields with Saprolite** (E. Aluli)

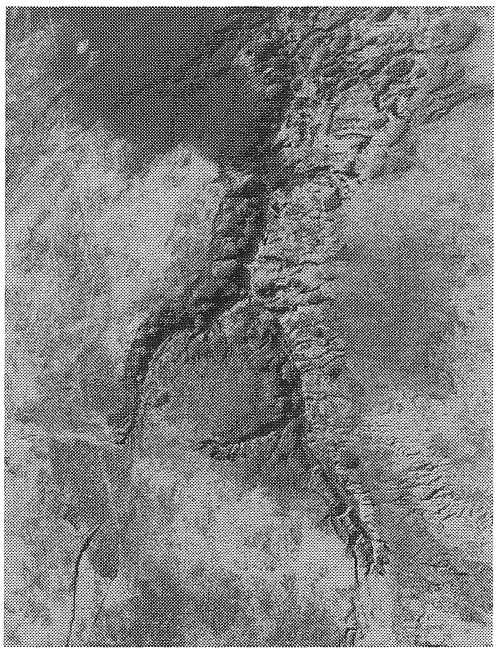


map 4.4



Deep Gullies and Headcuts

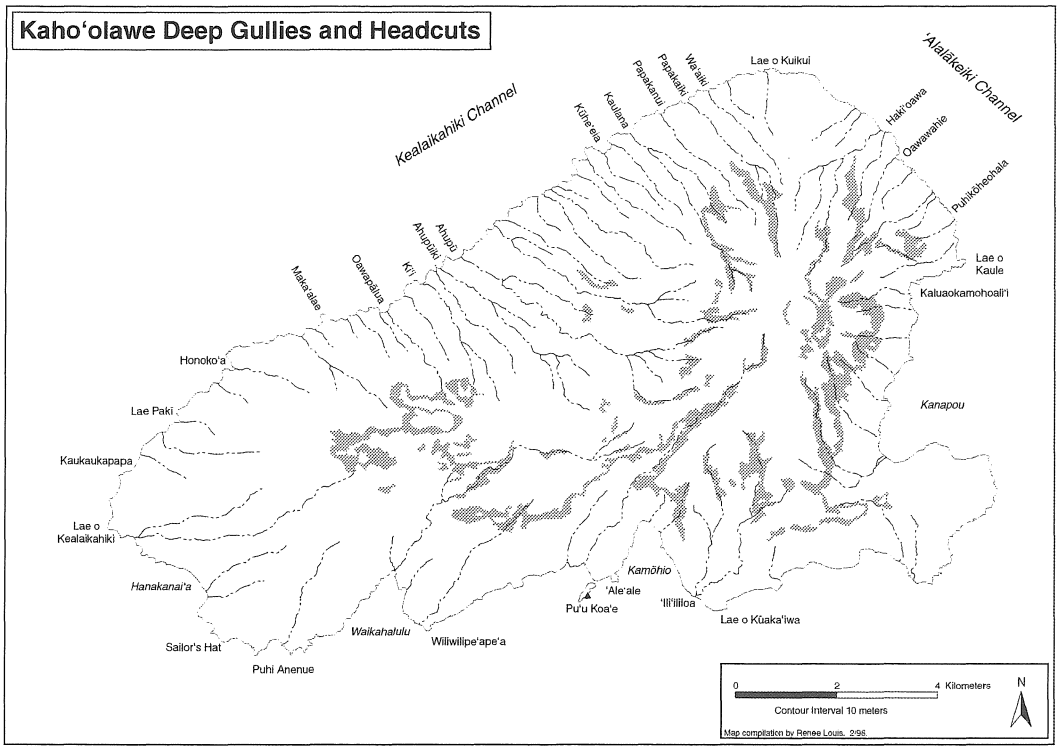
photograph 4.6: **Headcuts North of LZ-3 along K-2**
(S. Enomoto)



Sheet flow runoff from the hardpan form deep gullies and headcuts, which cover approximately 2,334 acres. Compared to "boulder fields with saprolite," the exposed saprolite in the gullies is generally more protected from the wind and sun – greatly reducing moisture stress. Other areas are nearly vertical and unstable.

Deep natural gulches – such as those near Hakioawa, Ahupū, Kaneloa, and Waikahalulu – are often typed together with the "deep gullies" eroded landscape, as they originate from similar circumstances. Their role on Kaho'olawe, however, is somewhat different. Freshwater (without sediment loads) from these gulches contributes to nearshore ecosystems. Erosion mitigation techniques will be similar to those for deep gully and headcut areas.

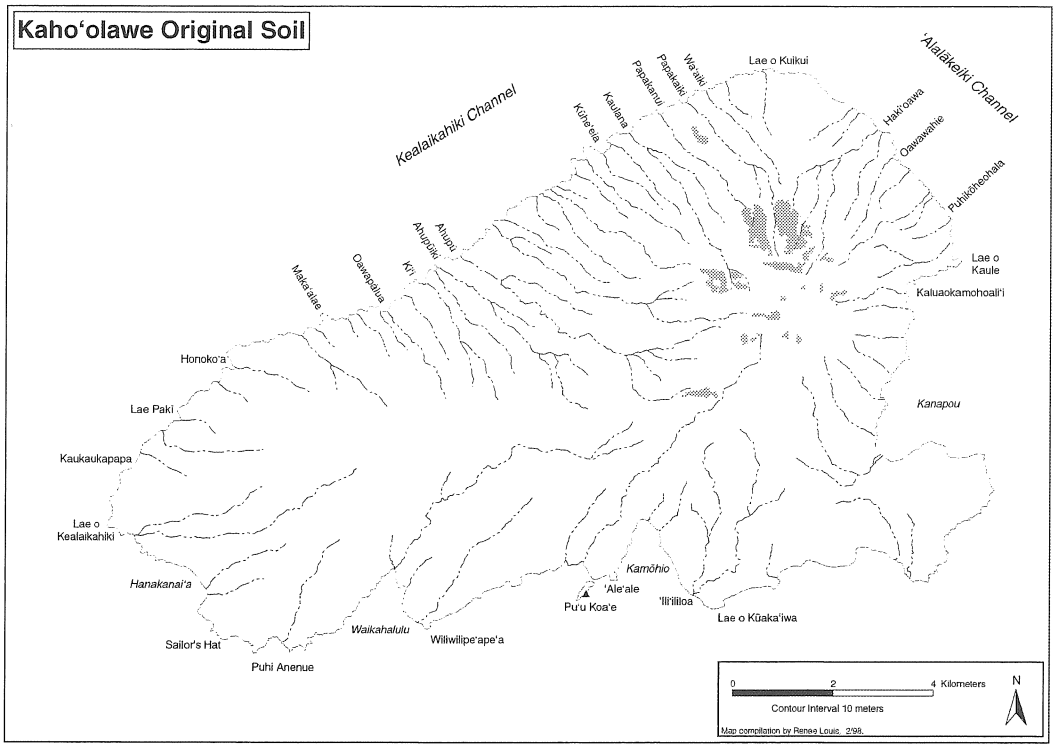
map 4.5



Remnant Upland Soils

Primarily located on the northern slopes of the summit, remnants of Kaho'olawe's original soil are still present. These pockets could serve as a natural, native seed bank. In addition, they are a rich resource for soil inoculum. The almost 355 acres of these soils are found as either small pedestals or large fields across the undissected hardpan.

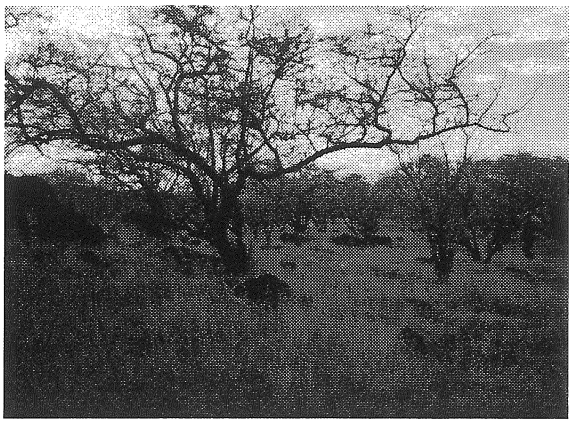
map 4.6



Kiawe-Buffelgrass

Two-thirds of Kaho'olawe is blanketed with a kiawe-buffelgrass savanna. Kiawe serves as a "water pump" and can lower the water table in coastal areas. Buffelgrass is one of Hawai'i's most notorious grasses for crowding out natives and providing fuel for a grass-fire cycle. Even so, from an erosion control perspective,

photograph 4.7: **Kiawe near Kūheʻeia** (S. Enomoto)

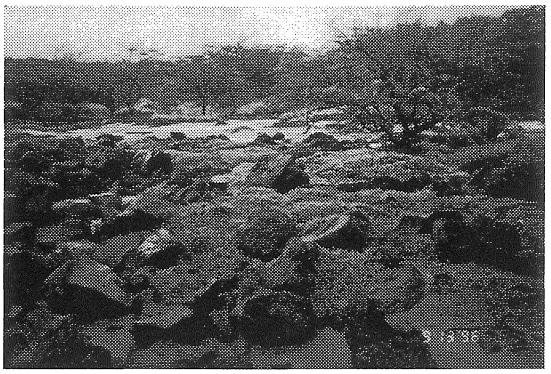


these species have contributed to the stability of the island's lowland areas and soil ecology. Restoration in these areas will focus on replacing these species with a more diverse array of native species.

Coastal Kīpuka

Located mainly in the coastal strand, kīpuka of remnant native plant ecosystems are important. They serve not only as vestiges of vegetation present on Kaho'olawe prior to the ranching era, but also as a "seed source" for regenerating native species critical to the island's healing process and preserving gene banks unique to Kaho'olawe. These kīpuka serve as reference ecosystems to illustrate of what may evolve as the restoration of the island proceeds. Potentially, they may provide sources of soil microbes for propagation and restoration. KIRC will monitor these areas and institute management measures to eradicate invasive alien species and expand the perimeters of these areas.

photograph 4.8: **Kīpuka near Kaukaukapapa** (K. Fairbanks)



Kahua Kauhale

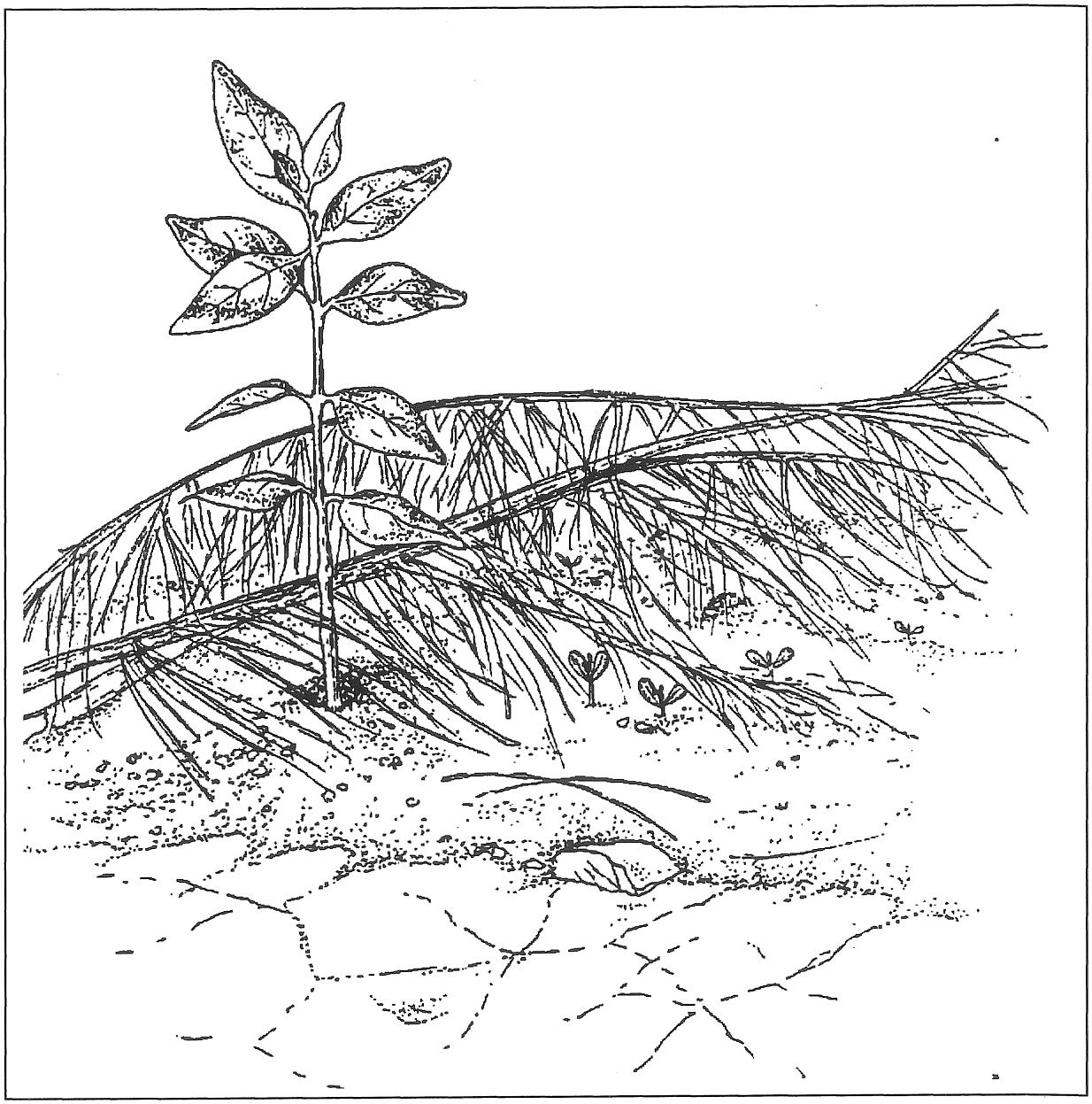
The development of gardens around base camps and kahua kauhale provide an excellent opportunity to employ traditional Hawaiian dryland planting practices recorded in the islands. They offer a chance to propagate culturally significant plants, including Polynesian introductions and lā'au lapa'au.

KIRC-Navy Coordination

Coordinating KIRC's and the Navy's revegetation and erosion control strategies during the cleanup also will be key to a successful restoration. KIRC and the Navy will develop *Erosion and Runoff Control Standards*, mutually acceptable mitigation measures for any ground disturbance. Infrastructure to support access to the island, water supply, equipment storage, staff accommodation, and roads will be needed for both the unexploded ordnance cleanup and the environmental restoration of Kaho'olawe. Thus, KIRC and the Navy will cooperatively design and

construct infrastructure that serves both the cleanup and the longer-term environmental restoration. Additional coordination will occur to secure native plants and seeds, establish nursery facilities, provide irrigation water, share equipment, and coordinate work schedules and logistics.

Restoration Strategies



Chapter 5

Planting Materials

Collection

Collection of native planting materials is done by hand. Several considerations are important when gathering seeds, seedlings, and cuttings:

- appropriate chants and offerings;
- proper collection techniques;
- management of source sites;
- seed cleaning and storage;
- propagation;
- seeding periods;
- germination and sowing methods;
- plant status; and
- cultural significance.

Documentation of collection practices will help to develop and maintain an adequate and viable supply of planting materials throughout the restoration.

Sources

KIRC will emphasize native plants believed to have formed the vegetation of ancient Kaho'olawe. The amount of appropriate source material on Kaho'olawe is extremely limited. Therefore, initial seeds, seedlings, and cuttings will come from

- native species from the Hawaiian archipelago, especially Maui Nui,
- Polynesian introductions, and, if necessary,
- non-invasive alien species.

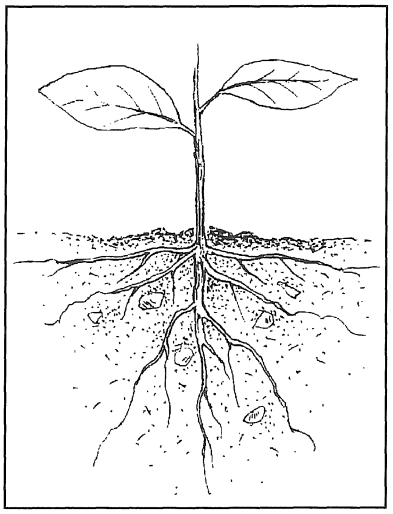
Plant and seed sources from Maui Nui, particularly areas which face Kaho'olawe and share similar elevations, are preferred. If the supply of

native planting material is still insufficient, KIRC will consider native species from throughout the Hawaiian Islands for planting material sources. All source materials will be carefully screened and monitored for diseases and undesirable alien pests.

Propagation

Seeds, seedlings, and cuttings will be propagated at KIRC facilities and volunteer "backyard" nurseries. Planting materials may also be purchased. Watering, fertilizing, inoculation, seed storage, and initial hardening will be done at KIRC's Maui nursery. Propagation and handling protocols will include requirements for sterile potting soil to prevent transfer of pests and disease, and for biodegradable containers to reduce excess weight and rubbish on island. In addition, grower certification, quality control, inspection, and quarantine programs may be instituted to insure production of healthy, disease- and pest-free plants.

sketch 5.1: **Outplanting Root**



Plants for restoration outplanting must have a well-branched primary (tap) root and limited leaf growth. Using appropriate containers can encourage this growth pattern. Trials will be conducted to determine which native species benefit from taproot air-pruning and which prefer retention of a single tap root.

A seed storage facility will be integrated into the Maui nursery because of the seasonality of treatments and collection times, and the number of planting materials required. Once seeds are gathered, KIRC will estimate viability and remove debris, empty or damaged seeds, and unfilled or dry seeds. Seeds will be cleaned and dried to ensure there is no transfer of pests and diseases. Research will be needed to determine whether any seeds require additional ripening time or conditioning before being planted. Utilization of information already known and available from seed storage laboratories will be important. Accurate and regularly updated records will be critical to ensure proper rotation of seed stock.

KIRC will develop a self-generating, on-island seed and cutting source, which should become viable in three to five years. A series of small

holding facilities will be developed on-island to acclimate large numbers of plants to the drier, more exposed conditions on-island.

Transport to Kaho'olawe

All planting material will be inspected for pests and disease before being moved to Kaho'olawe. Plants and seeds will have to be transported to Kaho'olawe as gently as possible to prevent damage or loss. Therefore, consideration must be given to packing seeds, seedlings, and cuttings for sea or air transport.

Recommended Species

Ideal characteristics for native flora species used for initial restoration and erosion control include:

- controls erosion;
- tolerates heat, drought, wind, fire, and nutrient-starved soils;
- contributes to soil rebuilding;
- survives among alien species populations;
- propagates easily;
- is readily available;
- pollinates and disperses seeds successfully;
- has a long life;
- has food, medicinal, or cultural importance; and
- contributes to faunal habitat restoration.

The following species are recommended for use throughout the restoration effort:

TREES

'ahakea (*Bobea sandwicensis; B. timonioides*); 'iliahi (*Santalum freycinetianum*);
a'ia'i (*Streblus pendulinus*); keahi (*Nesoluma polynesicum*);
'aiea (*Nothocestrum latifolium*); koai'a (*Acacia koaia*);
'akoko (*Chamaesyce stokesii*); kōlea (*Myrsine lanaiensis; M. Lessertiana*);
'āla'a (*Pouteria sandwicensis*); kou (*Cordia subcordata*);
alahe'e (*Canthium odoratum*); kukui (*Aleurites moluccana*);
'ānapanapa (*Colubrina asiatica*); kulu'ī (*Nototrichium sandwicense*);
hala (*Pandanus odoratissimus*); lama (*Diospyros sandwicensis*);
halapepe (*Pleomele auwahiensis*); mai'a (*Musaxparadisiaca*);
hao (*Rauvolfia sandwicensis*); māmane (*Sophora chrysophylla*);
hau (*Hibiscus tiliaceus*); maua (*Xylosma hawaiiense*);

mehame (*Antidesma pulvinatum*);
milo (*Thespesia populnea*);
nānū (*Gardenia bighamii*);
niu (*Cocos nucifera*);
'ohe makai (*Reynoldsia sandwicensis*);
'ōhi'a (*Metrosideros polymorpha*);
ololpua (*Nestegis sandwicensis*);
'ulu (*Artocarpus altilis*); and
wiliwili (*Erythrina sandwicensis*).

SHRUBS

'a'ali'i (*Dodonaea viscosa*);
'ākia (*Wikstroemia uva-ursi, W. oahuensis*);
'akoko (*Chamaesyce celastroides*);
'awa (*Piper methysticum*);
'āweoweo (*Chenopodium oahuense*);
'iliahi alo'e (*Santalum ellipticum*);
'ilie'e (*Plumbago zeylanica*);
'ilima (*Sida fallax*);
kī (*Cordyline terminalis*);
kokio (*Hibiscus kokio*);
kolokolo kahakai (*Vitex rotundifolia*);
kolomona (*Senna gaudichaudii*);
ko'oko'olau (*Bidens menziesii, B. molokaiensis*);
ko'ola kea (*Abutilon incanum*);
ko'ola 'ula (*Abutilon menziesii*);
kūpaoa (*Dubautia linearis*);
maiapilo (*Capparis sandwicensis*);
ma'o (*Gossypium tomentosum*);
ma'o hau hele (*Hibiscus brackenridgei*);
naio (*Myoporum sandwicensis*);
naupaka kahakai (*Scaevola sericea*);
naupaka kuahiwi (*Scaevola gaudichaudii*);
nehe (*Lipochaeta integrifolia*);
'ohai (*Sesbania tomentosa*);
pūkiawe (*Styphelia tameiameiae*);
'ūlei (*Osteomeles anthyllidifolia*); and
wauke (*Broussonetia papyrifera*).

HERBS

'ākulikuli (*Sesuvium portulacastrum*);
'ala'ala wainui (*Plectranthus parviflorus*);
hinahina (*Heliotropium anomalum*);
'ihi (*Portulaca lutea, P. molokiniensis, P. villosa*);
kalo (*Colocasia esculenta*);
'ōhelo kai (*Lycium sandwicensis*);
pāwale (*Rumex giganteus, R. skottsbergii*);
puakala (*Argemone glauca*); and
'uhaloa (*Waltheria indica*).

VINES

'ānunu (*Sicyos* spp.);
'āwikiwiki (*Canavalia pubescens, C. hawaiiensis*);
huehue (*Cocculus trilobus*);
hunakai (*Ipomoea imperati, I. tuboides*);
kauna'oa (*Cuscuta sandwichiana*);
koali (*Ipomoea indica*);
koali 'ai (*Ipomoea carica*);
kūpala (*Sicyos pachycarpus*);
pā'ū o Hi'iaka (*Jacquemontia ovalifolia*);
pōhuehue (*Ipomoea pes-caprae*);
'uala (*Ipomoea batatas*);
(*Bonamia menziesii*);

FERNS

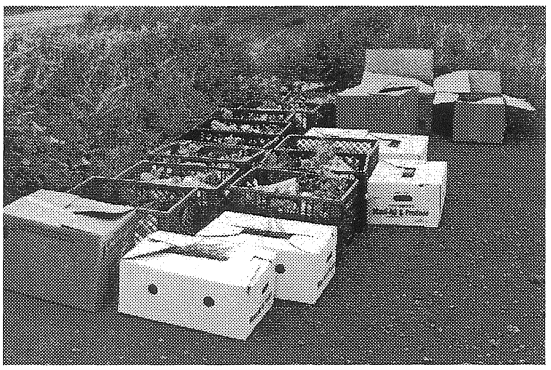
kalamoho (*Pellaea ternifolia*);
kīlau (*Pteridium aquilinum*);
kumuniu (*Doryopteris* spp.);
kupukupu (*Nephrolepis exaltata*);
moa (*Psilotum nedum*);
pala'ā (*Sphenomeris chinensis*); and
uluhe (*Dicranopteris linearis*).

GRASSES AND SEDGES

'aki'aki (*Sporobolus virginicus*);
kākonakona (*Panicum* spp.);
kāwelu (*Eragrostis variabilis*);
makaloa (*Cyperus laevigatus*);
pili (*Heteropogon contortus*);
(*Carex wahuensis*);
(*Eragrostis atropioides*);
(*Fimbristylis* spp.);
(*Gahnia* spp.); and
(*Mariscus hillebrandii*).

Number of Plants Required

photograph 5.1: **Propagules near Lua Makika**
(P. Levin)



The number of plants required for the revegetation of the island can only be very roughly estimated. For planning purposes, KIRC has developed an estimate based on past restoration efforts and a series of assumptions. Of the roughly 12,800 acres that has been severely eroded, KIRC assumes it will attempt to restore about one-third (or, 4,300 acres). Of the area targeted for restoration, KIRC will strategically treat one-fifth (or about 860 acres), allowing the other four-fifths to revegetate through natural processes. Each acre would receive twenty trees, two hundred shrubs, and 7,600 plugs of grasses and vines. KIRC also assumes that in this treatment live plants would be used and no seeds would be broadcast. If this method were used exclusively for ten years (planting 86 acres annually), KIRC would require 1,720 tree saplings, 17,200 shrub seedlings, and almost 654,000 grass and vine plugs annually. If an average amount of rain fell at the summit (twenty-five inches), and if KIRC were able to water plants through the first dry season, about 80 percent of the plants would probably survive. If watering did not prove feasible, about 40 percent would survive. In either case, additional plants would be needed each year to replace those that die. The logistical and support requirements for sustaining 86 acres per year of outplanting exceed the KIRC's capacity at this time. Alternatives using seeds and cuttings placed in erosion control structures, broadcast seeding, and other methods will be explored. This may alter the plant and seed requirements.

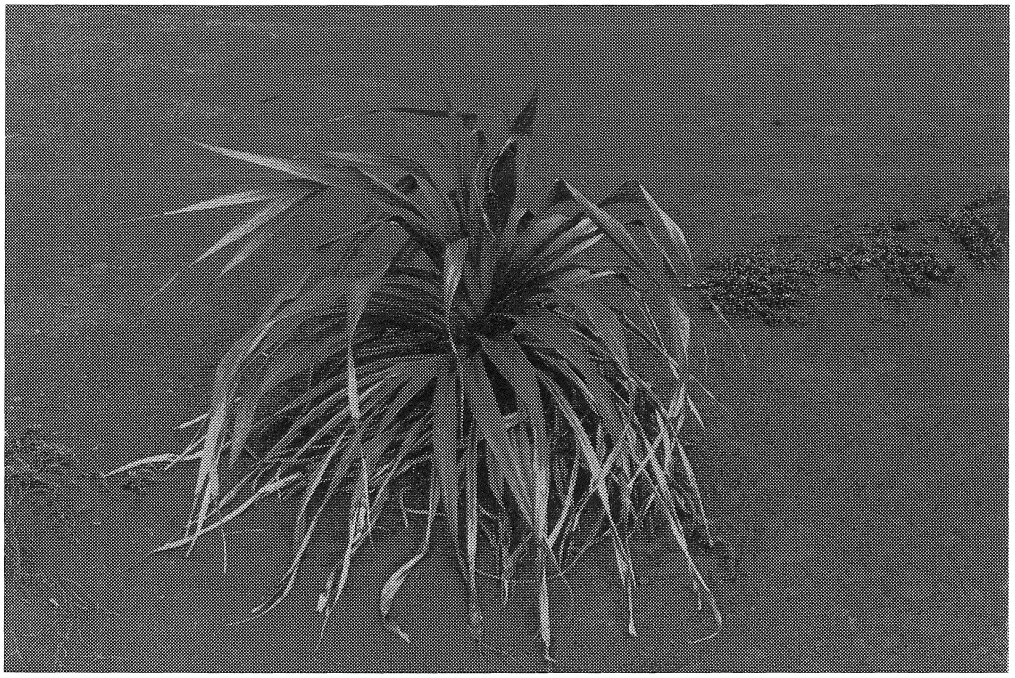
Use of Alien Species

The difficulty of propagating native plants and collecting native seeds in large numbers may require use of alien species for initial erosion control efforts. Native species will replace alien species as planting materials

become available and soils are stabilized and regenerated. Care will be taken to balance the use of alien species against the goal of reestablishing native ecosystems. Environmental, labor, time, and resource costs will be weighed carefully to ensure that other, more difficult ecological problems are not created for the future. Desirable characteristics for non-native species are:

- currently on Kaho'olawe;
- non-alleopathic (not toxic to other plants);
- relatively susceptible to replacement by native species and communities;
- fast-growing;
- short-lived;
- does not create a high fire fuel load;
- necessary for a specific requirement (*e.g.*, soil retention, windbreak); and
- removable without contributing further to erosion.

photograph 5.2: **Hala** (P. Levin)



Chapter 6

Field Implementation

Site Planning

Fully understanding the natural processes and characteristics of a particular site is critical to achieving restoration success. Site characteristics will be assessed and site-specific plans developed for each area. These plans will aid in coordinating staff and volunteer work.

Site Analysis

Baseline data contained within a site analysis will assist in developing the *Site Plan*, monitoring changes to the local environment, and evaluating restoration activities over time. The site analysis should seek information on the area's:

- history (natural, human, geological);
- location and features (cultural or archeological resources, physical topography and natural features, slope, elevation, aspect);
- soil description, analysis, and water infiltration rate;
- climate and microclimates (rainfall, wind direction and intensity);
- microhabitats (ditches, gullies, boulders or rocks, bomb craters or depressions);
- hydrogeology (maps of water, wind, and soil flows on and between sites);
- existing vegetation (description, species, estimate of native and alien species cover, alien plant threats);
- faunal considerations (species present, potential impact on and by fauna);
- ordnance clearance (surface, subsurface, none) and location; and
- desired end-state ecosystem.

Besides baseline data, information on resources available for revegetation, such as location of harvestable resources (*e.g.*, windbreak or mulch materials), will be needed.

Site Plan

From the baseline analysis, a preliminary site plan will be prepared. This plan will help to ensure a common strategy for each area, clarification of the desired end-state, and plant design and layout for erosion control and revegetation. This plan should direct restoration workers:

- where to plant (site-specific plans and site preparation);
- when to plant (timing);
- what to plant (characteristics, species selection, sources, and propagation); and
- how to plant (logistics, soil reconditioning, treatments, care and management).

Timing

KIRC will develop a seed and cutting collection calendar. In general terms, collection will be done March to May, nursery propagation and site preparation throughout the dry season (March to October), on-island acclimatization during September and October, and installing containerized plants or seeds in the wet season (November to February).

In order to determine successional status (*e.g.*, when to plant a particular species vis-à-vis the overall restoration program), the following information for each species will be collected: pollination ecology, seed dispersal technique, and gene flow. This information will assist KIRC in designing treatment locations and species sequences.

Archaeological Sites

Almost 72% of the inland archeological sites (557) are across the undissected hardpan, with a high concentration near the summit. An even greater number is found along the coastal strand. As erosion control and revegetation proceeds, these sites will be addressed in a culturally appropriate manner that is consistent with historic preservation law. Site protection will vary according to the nature and context of the cultural resources contained therein. Possible treatment may include recordation, avoidance, stabilization, preservation, rehabilitation, restoration, reconstruction, or use for educational and cultural purposes. Such activities will follow the *Site Protection Agreement* between the Navy, the State Historic Preservation Division, and the Kaho'olawe Island Reserve Commission.

Site Preparation

Reconditioning and Preparing the Soil

A limited number of insects, microorganisms, and other small invertebrates live in soils on Kaho'olawe. They may not exist, however, in sufficient numbers to reestablish healthy soil ecology. Soil communities will be monitored periodically to determine the need for reintroduction of microorganisms. Baseline information on the composition of soil biological communities will be collected in appropriate reference ecosystems.

Plants will be inoculated with *mycorrhizae* in order to increase development of healthy soil ecology. There are three sources of these organisms: (a) inocula gathered from soils of appropriate native plant communities; (b) fungi (*i.e.,* vesicular-arbuscular *mycorrhizae* or VAM) isolated from native soils; and (c) commercially-available isolates of certain species of fungi (*i.e.,* VAM). Inoculating plants with *mycorrhizae* and *rhizobium* (symbiotic nitrogen-fixing bacteria) from local sources will occur as soon as availability is secured. Time constraints, however, will probably necessitate initially applying commercially available innoculum. Procedures for propagating *mycorrhizae* and inoculating plants will be developed.

Chemical fertilizer may be required either because

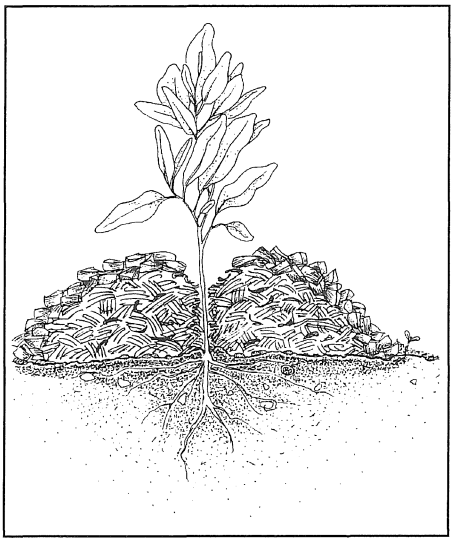
- nutrients are deficient for vigorous plant growth, or
- enhancement of soil organisms is required to restore degraded soil ecosystems.

Fertilizer will be applied in planting holes and incorporated into the soil at the time of outplanting, or broadcasted with seed. KIRC will monitor the results of fertilizer usage and include the results into their database for evaluation. In general, KIRC will supplement fertilizer with organic matter wherever possible.

Mulch will be used as a soil surface cover. These dry pieces of organic material, comparatively large and heterogeneous in size, will eventually "compost down" to become more soil. It helps to prevent erosion, trap sediment, cool soil, and assist in water absorption. Mulch will be harvested in short rotations from areas planted with fast-growing species to prevent seeding. Kiawe chips can be used for erosion control and mulching, though realistically it cannot meet all on-island needs. There are

other sources of mulch on Kaho'olawe, including alien grasses. In addition, a traditional Hawaiian practice, rock mulching, traps moisture and soil under plants and provides a cooling effect. Use of off-island sources for organic matter has been suggested, but the risk of introducing alien pests is high.

sketch 6.1: **Mulch Technique**



Tilling by hand or machine in areas cleared of UXO is one method for opening the hardpan crust. Reopening the soil surface will be necessary to allow plants to take root and will increase percolation immediately. To mitigate wind and water erosion, a rough, cloddy surface will be created with the tiller. A soil sealant (*e.g.*, hydromulch) may be considered, although it may be prohibitively expensive for extensive use.

The Savory system of holistic resource management will be considered to prepare the soil in certain areas. This technique, which consists of a controlled number of ungulates grazing within a fenced area, has been shown to improve degraded ecosystems, thereby aiding the restoration of native plant communities. The animals' eating reduces alien grass cover; their walking and manure droppings fertilize and spread seeds and microorganisms into the soil. Once the soil has been turned, fertilized, and alien species grazed back, the animals would be moved to another location.

Fire

Prescribed burning may be considered as a strategy to prepare areas choked with alien grasses and trees. Fire has been shown to enhance successful competition by native plants in some instances and to favor aliens in others. The use of fire for site preparation will be exercised with extreme caution.

Erosion Control Structures

KIRC intends to control erosion with wattles, fascines, windbreaks, and swales. Other techniques, such as geotextiles, check dams, and gabions also may be employed (Appendix 6). Extreme care will be taken when

setting out manmade structures or modifying the topography to avoid channeling or concentrating the runoff. As erosion control efforts continue, those techniques that prove most successful will be modified and applied in other areas.

Treatments for Landscape Types

KIRC will use a diverse set of techniques for erosion control and revegetation, using structures, seeds and live plants. The specific methods used at each site will be based on the level of ordnance clearance, topography, the cost of providing water, mulch, soil supplements, and the ability of planting or seeding techniques to contribute to redeveloping a native ecosystem. Appropriate cultural ceremonies will be conducted.

Seeds will be used extensively in erosion control treatments. For example, they may be incorporated into mulch or planted in accumulated soil. Native seeds will be broadcast to take advantage of planned or unplanned fire events. Seeds may be planted in alien-dominated areas so as to encourage their conversion to native ecosystems. Outplanting probably will be done less extensively than seedings, due to cost and safety considerations. Areas to be tilled will be closely checked against ordnance clearance records.

Undissected Hardpan

Undissected hardpan sites will be addressed through the use of berms, swales, branch wattles, mulch, windbreaks, and geotextiles. Tilling will be limited to subsurface cleared areas. Soil reconditioning will be considered.

Methods that accumulate soil and organic matter and enhance kīpuka will be emphasized. Specifically, bunch grasses should be planted or its seeds broadcast into strips that have been either tilled or mulched. 'Aki'aki will be planted or seeded on the upslope side of each strip. The downslope side will receive strategically placed plantings along the contour (*i.e.*, follow topography without concentrating water flows), next to a berm. These plantings should contain grasses and fast growing, woody shrubs and trees.

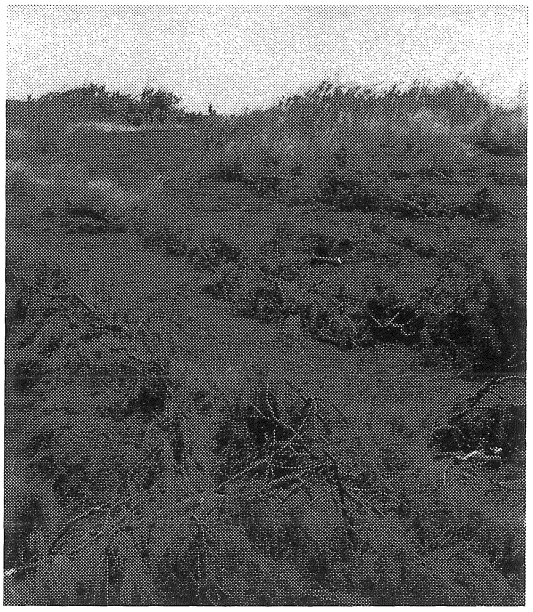
Dissected Hardpan

In areas of dissected hardpan, windbreaks, mulch, berms, swales, fascines, wattles, and geotextiles will be used to trap sediment and to reduce runoff entering gullies. The soil will also be reconditioned. In each gully, KIRC will stake fascines or wattles to mitigate and manage erosion flows. ʻŪlei, ʻaʻaliʻi, ʻāweoweo, kāwelu, and hau have been suggested for planting. Seeds of these species will be placed in fascines. Fertilizer may be applied. Trees for windbreaks will be planted mauka of fascines and at every advantageous site in areas between gullies.

Rilled Plateau

In rilled plateau areas, branch and grass wattles, swales, small check dams, mulch, geotextiles, and windbreaks will be used to trap sediment and control erosion at strategic runoff points. Areas above the headcuts will be planted with shrubs as mulched contour hedgerows. Fertilizer and seed will be broadcast. As with other erosion control strategies, work should be initiated from the top of the landscape. Some rilled plateau sites appear somewhat protected; while in other areas tree planting may be required as windbreaks. Removal of upwind kiawe will be delayed, as they protect plantings from excessive wind and drying.

photograph 6.1: **Branch Bundles near Lua Makika**
(P. Levin)



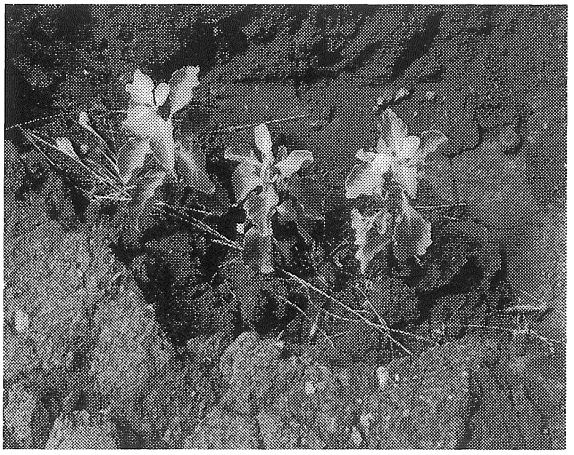
Boulder Fields with Saprolite

Wattles, mulch, and geotextiles will be used to catch soil in boulder fields with saprolite. The soil will also be reconditioned. Since the terrain prohibits vehicular access and requires hand planting, seedlings and seeds will be placed at the upslope, upwind ends of the boulder fields in depressions at the onset of the rainy season. Native species, such as ʻaʻaliʻi, koʻokoʻolau, ʻuhaloa, and pili, have high seed production and germination rates appropriate to the needs of this landscape type. A dolomite lime supplement may be required to compensate for acidic soils.

Deep Gullies and Headcuts

Stabilization efforts should not begin until the overland flow that causes a particular gully is reduced, unless an important cultural site or road necessitates extraordinary protection. If mauka efforts sufficiently curtail erosion, these areas may partially revegetate over time without direct human intervention. Over the years, a great deal of ordnance has accumulated in the deep gullies and natural gulches, carried there by heavy rains.

photograph 6.2: **Planting in a Gully Headland near Lua Makika** (P. Levin)



Remnant Upland Soil

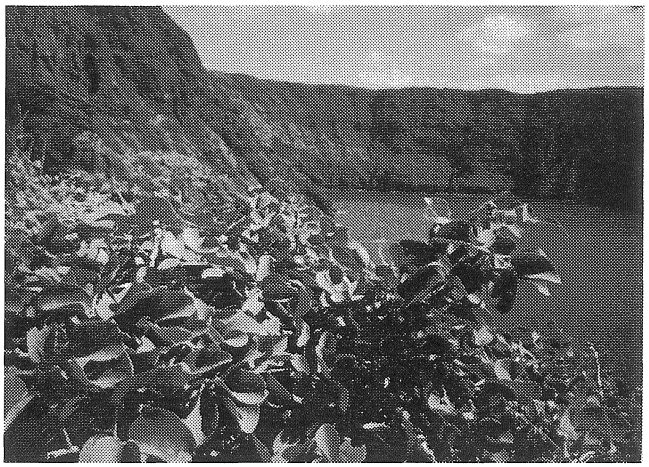
KIRC will investigate how to utilize the native seed banks and intact soil ecology found within remnant upland soils. As in kiawe-buffelgrass areas, techniques that assist natives to compete successfully with established exotics will be used.

Kiawe-Buffelgrass

From an erosion control perspective, the kiawe and buffelgrass have contributed to the stability of the island's lowland areas. Any widespread attempt to remove these plants may increase erosion. Therefore, KIRC must exercise caution when preparing these sites for treatment. KIRC will plant ʻaʻaliʻi and ʻāweoweo in subsurface cleared areas, and broadcast their seeds at other sites. These native species grow quickly and produce heavy shade, which should help to block out further germination of alien grasses.

Coastal Kīpuka

photograph 6.3: **Kanaloa on 'Ale'ale** (S. Enomoto)



KIRC will monitor coastal kīpuka, institute management measures to eradicate invasive alien species, and enhance reproduction of existing native species. To facilitate self-seeding, KIRC will selectively weed or implement other activities to make plants healthy and improve their vigor. KIRC will also encourage expansion of kīpuka by clearing alien species from the outside margins.

Kahua Kauhale

Plant species selected for kahua kauhale sites tend to have higher water and soil nutrient requirements. Therefore, deeper reconditioning of the soil may be necessary, particularly for root crops. Seedlings and cuttings will be the primary method for initial outplantings.

photograph 6.4: **Pā'ū o Hi'iaka** (P. Levin)

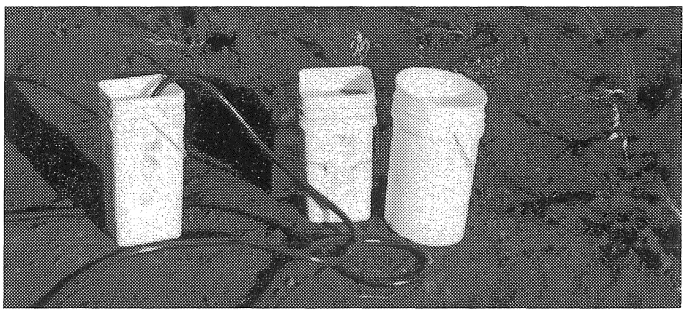
Chapter 7

Care and Management

Watering

Restoration treatments require water, but there is no large, reliable source on the island. Therefore, not all plantings and seedings can be irrigated, and water needs must be balanced with the limitations of a depleted resource. A combination of site-specific and island-wide plans will be developed to effectively apply the limited water available.

photograph 7.1: **Hand Watering near Lua Makika** (P. Levin)



Plants and seeds should be watered by hand when they are initially put into the ground, unless a heavy rain soon follows. Irrigation during the first dry season will probably double survival rates. Irrigation costs are high, and water through the first dry season will be done selectively. To water by hand, for example, it would take 2 people 1 day to water about 2,000 plants. Planting and seeding will be done in the rainy season to reduce initial water needs. Early revegetation efforts will focus on dryland plants that can survive and reproduce on Kaho'olawe with little water. Ideally, each plant would receive one quart of water at the time of planting, and one-half gallon each month throughout the first dry season.

Alien Plant Control

Non-native plants compete for water and nutrients. Some species chemically inhibit the growth of plants in adjacent areas, and rapidly colonize new sites. Alien plant invasions can alter entire ecosystems, forming monotypic stands (dominated by one species), modifying fire

characteristics of native communities, altering soil-water regimes, changing nutrient cycling, and encouraging other nonnative to establish themselves on-island.

Control and Eradication Measures

KIRC will closely monitor alien plants. A quarantine and prevention program will be instituted to guard against the introduction and establishment of new alien species. Where technically and financially feasible, undesirable non-natives plants will be eradicated. An effective quarantine program includes:

- inspection and cleaning of all materials going to the island;
- detection and identification of potential pests; and
- containment and eradication of harmful organisms *before* they reach Kaho'olawe.

In addition to quarantine procedures, a rapid response to the discovery of a newly introduced species will be implemented to prevent the establishment or spread of alien flora. Manual, mechanical, and chemical eradication methods are possible. After plants are removed, the area will be inspected for seeds, which could germinate and grow or blow to adjacent sites. Follow-up monitoring will also be necessary

Weeding

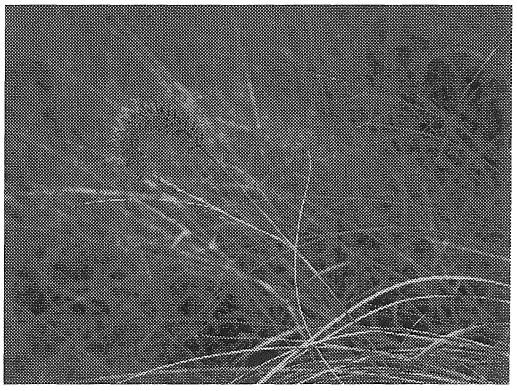
Regular weeding will be required, around and within planted areas and near individual trees and shrubs, on a monthly basis during and just after the rainy season. Removing alien species before seed heads develop will reduce the spread of weeds by wind, water, birds, or rodents, and will provide additional mulch resources.

Categories of Alien Plant Species

A host of alien species currently grows on Kaho'olawe. It is technically and financially unrealistic to eliminate them all. Some pose a serious threat to native plants and the success of the restoration and should be eradicated. Others probably cannot be eradicated, but may be controlled. Still others have proven beneficial to the natural revegetation of Kaho'olawe. Many aggressive alien species that have invaded other areas of Hawai'i are not currently found on the island.

Four species of alien plants have proven to be very harmful to native ecosystems in other parts of the state. Since they are not widespread on Kaho'olawe, it is technically and financially feasible to eradicate them. These species are tinaroo, ironwood, fountain grass, and *Cenchrus tribuloides*.

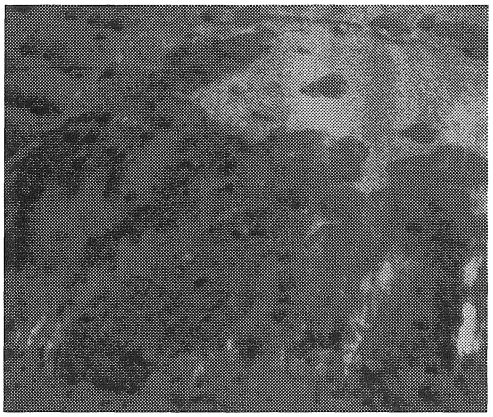
photograph 7.2: **Fountain Grass** (P. Levin)



Some weeds are so well established that no practical means currently exists to completely eradicate them. Instead, these species will be controlled; eventually moving populations toward. The list of potentially controllable alien species includes: lantana; koa haole; molasses grass; giant Guinea grass; and sourbush. The distribution and abundance of these species will be assessed in order to evaluate the feasibility of controlling them.

Australian saltbush and tamarisk have contributed to the natural revegetation of the island. Australian saltbush is a colonizer rather than an invasive species and captures soil blowing across the hardpan in small hummocks. The individual plant dies back within two years, providing organic matter to the soil and those plants that have germinated in its hummock. Tamarisk has served as an effective windbreak for a large area near Lua Makika. Loose soil has built up between tamarisk rows and native and alien plants have taken root. This particular species has not reproduced naturally on Kaho'olawe in over twenty years. Related species, however, have aggressively spread in other parts of the world, becoming a serious ecological problem. KIRC will monitor tamarisk, and plant native species between tamarisk rows to take advantage of the protection they provide.

photograph 7.3: **Fire on Kaho'olawe** (P. Higashino)



Fire Prevention

Prescribed burning may be used as a site preparation technique for both UXO clearance and native plant revegetation. The potentially negative impacts, however, of uncontrolled fires, must be addressed and mitigated. The ordnance-related risk of explosion, coupled with the fire-prone nature of

the island's vegetation, creates a high fire risk on Kaho'olawe. As restoration progresses and vegetation covers more of the island, fire will become a greater threat to the long-term maintenance of native vegetation. A single, uncontrolled fire could sweep across large areas, devastating prior work. Due to the danger to human life from UXO, the Navy and KIRC will not fight any wildfires. Therefore, measures must be taken to minimize the risk of an uncontrolled fire.

Planting Strategy

To lower the risk of fire, the planting strategy described in this plan emphasizes structural and compositional diversity. This will ultimately be the best long-term fire protection measure. The restoration effort will emphasize use of native shrubs and trees, and reduce the presence of grasses. A small percentage of native flora tolerate disturbance conditions, such as fire, including 'a'ali'i, pili, and 'uhaloa. KIRC needs to acquire additional information on:

- the impact of surface litter on fire;
- the ratio of dead to live fuels before and after burning;
- seasonal variation in plant and soil moisture and their effect on fire risk;
- flammability of different plant species;
- the relationship between site histories and response to fire;
- seed sources before and after fires;
- predation;
- production patterns before and after fires; and
- the effect of fire intensities and frequencies on native and alien species.

Fire Atlas and Management Plan

A *Fire Atlas* should be developed for the cleanup, restoration, and management of Kaho'olawe. The atlas could be similar to those developed for parts of the Island of Hawai'i and for which a methodology and considerable information on environmental conditions similar to Kaho'olawe already exists. The document should encompass:

- an assessment of the risk of fire throughout the island;
- maps of the fire risk incorporated into the Kaho'olawe geographic information system;
- sufficient information to allow the Navy and KIRC to examine short- and long-term effects of fire at each site slated for ordnance cleanup;
- the risk of fire spreading;

- potential impacts of burns; and
- an assessment of native plant density, erosive risk, and replanting potential.

KIRC will begin to develop a database for the development and updating of a *Fire Atlas* as initial surveys are conducted. The environmental effects of any fires on the island will be documented for inclusion in the database. This atlas should include a "fire danger rating system," a tool which defines the level of fire preparedness.

KIRC will develop a *Fire Management Plan*. This document will include contingency plans in the event of a fire, including provisions for necessary equipment, procedures for fire containment, water sources, and fire protection priorities. It will also delineate fire suppression measures, such as: revegetating with fire-adapted plants; using roads, gullies, and other corridors as fire breaks; and creating a fire response protocol. These will be developed and implemented in close cooperation with the Navy.

Fire Breaks

Roads and trails will serve as fire breaks between adjacent vegetated areas. In order to serve this function, roads should have a minimum of fifteen feet cleared on either side. These areas require regular maintenance, especially as grasses revegetate across the island. Other fire breaks should be established on ridge boundaries and around all high-ignition risk areas, such as power supply networks at base camps, human habitation sites, work areas and structures.

Mammalian Predator Control

Kaho'olawe supports populations of three mammalian predators: feral cats; house mice; and, possibly, Polynesian rats. Feral cats and house mice are found throughout the island, and the latter exhibits periodic late summer population explosions. Mice are the largest threat to seed and fruit survival. Cats prey on birds. The Polynesian rat has not appeared in trapping surveys since 1971. Norway rats and mongoose are not currently present on Kaho'olawe, and preventative quarantine requirements will be observed to inhibit their introduction. Removal of mammalian predators demands a high initial capital outlay. Unless a strict and successful alien species prevention program is established, large sums of money could be spent with little result. Eradication of mammalian predators will become more difficult as revegetation successfully proceeds.

As with all pest control programs, the effects of toxicants on non-target species must be considered in the decision-making process. On Kaho'olawe, toxicants will effect pueo and the surrounding marine ecosystems. These potential effects will remain a key consideration when implementing a toxicant-based mammalian predator control regimen. KIRC will proceed cautiously.

Chapter 8

Faunal Restoration

Culturally and ecologically, faunal restoration is an important component of a successful restoration program. The restoration of native birds, turtles, insects, and microorganisms will enhance the establishment of native ecosystems. Native bird and invertebrate populations will assist in seed dispersal and scarification, and add valuable nutrients to the ecosystem.

Avian

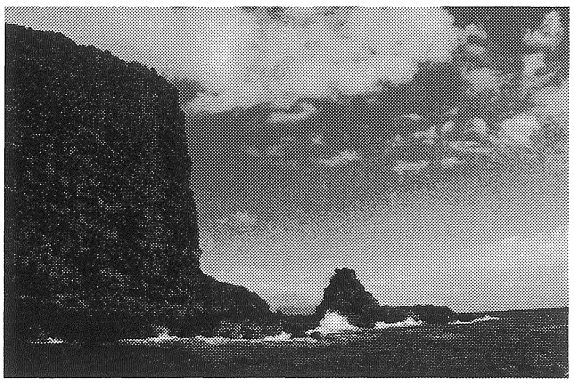
Restoring native bird populations on the island is contingent primarily on:

- control of alien predators;
- availability of suitable habitat for nesting, foraging, and shelter;
- availability of suitable food resources; and
- prevalence of diseases and the feasibility of controlling disease vectors.

After ordnance clearance, and as changes begin to occur in plant and animal communities, it will be possible to develop more detailed, comprehensive restoration plans for birds.

Seabirds

photograph 8.1: **Lae o Ka'ule** (S. Enomoto)



The majority of Hawaiian seabirds nest in colonies, often in very large numbers, and most return to their birth sites to breed. Habitat degradation on Kaho'olawe has contributed to catastrophic declines in seabird populations. Cats and other predators hunt seabirds.

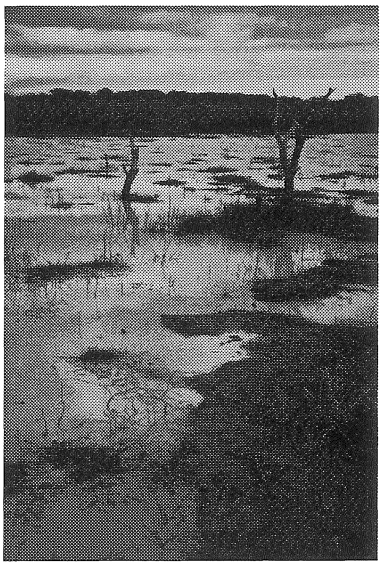
Removing this threat will allow for rapid, natural recovery of some seabirds. Attempts to attract seabirds, however, should not begin until the removal of mammalian predators. Additional attraction techniques or management will be required for many species, such as 'ua'u or 'ake'ake, which are rare and more sensitive. Pu'u Koa'e and 'Ale'Ale harbor native plants, seabirds, and migratory shorebirds and should be protected. KIRC will conduct population surveys to determine the distribution and abundance of seabird colonies on Kaho'olawe. Baseline data and a work plan for seabird attraction and nesting site restoration techniques, in conjunction with revegetation activities, will be compiled.

Shorebirds, Waterfowl, and Wetland Birds

Common migratory shorebirds already recorded on Kaho'olawe include kōlea, 'ūlili, 'akekeke, and hunakai. Kaho'olawe could potentially support more species of migratory birds. It may be possible to establish a breeding population of nēnē, given that the species requires little, or no, wetland habitat. Some endemic, non-migratory species of waterfowl and wetland birds, such as Laysan duck, koloa, 'alae ke'oke'o, 'alae 'ula, and ae'o might be successfully reintroduced to the island, if habitat conditions become favorable. Although generally considered an arid island, there are several wetlands on Kaho'olawe. Opportunities exist for protecting, enhancing, and restoring bird populations that use wetland habitats.

An understanding of the nature and distribution of past wetland habitats, as well as the potential of enhancing existent or future ones, is fundamental to restoring wetland bird species. The craters on Kaho'olawe have place names indicating their status as natural wetlands: Lua Keālialalo ("the pit of the low swampy land"); Lua Keālialuna ("the pit of the upper marshy land"); and Lua Makika ("mosquito hole"). It may be possible to create or recreate wetlands, especially if restoration managers establish swales and basins to collect water or to control erosion and run-off. The reestablishment of wetlands contributes to replenishing localized freshwater aquifers. In addition, the recreation of wetlands will allow KIRC to seek supplemental funding for endangered bird restoration (*e.g.*, Laysan duck).

photograph 8.2: **Lua Keālialalo** (S. Enomoto)



Owls

Two owl species are found on Kaho'olawe: the native pueo and the introduced barn owl. Pueo can tolerate climatic and vegetative extremes, inhabiting dry areas, wet areas, grasslands, and forests. It is a ground-nesting specie susceptible to attack by feral cats. Both pueo and barn owls feed primarily on rodents. Although barn owls are known to prey on seabird chicks and sometimes adults, and pueo are known to prey on native land birds, both species on Kaho'olawe probably subsist mainly on rodents. Little data is available on their seasonal densities or food habits. Eradication of rodents will remove the primary food base for both owls. As faunal restoration proceeds, pueo may be able to survive on birds and other prey, or emigrate to Maui. KIRC will consider barn owl control in order to protect seabirds.

Woodland and Shrubland Birds

It is not clear whether Hawaiian honeycreepers or other native songbirds could be brought to Kaho'olawe, since none live there now. It seems likely that songbirds once flourished here, as they did in similar environments on other Hawaiian Islands. Several obstacles, however, discourage their introduction. First, native songbirds are highly susceptible to two diseases, avian malaria and avian pox, which are transmitted by mosquitoes. Second, non-native cats and rats prey on birds and their nests. Species most suitable for initial introduction would be those suited to arid shrubland and forest, with generalized diets, and that can nest in a variety of sites. The only species meeting these requirements include: Laysan finch; Nihoa finch; millerbird; and 'amakihi.

Mammal

Native mammals consist of the 'ōpe'ape'a (Hawaiian bat) and the 'īlio holo i ka uaua (Hawaiian monk seal). Flora and faunal restoration of Kaho'olawe will not have an adverse impact on either species.

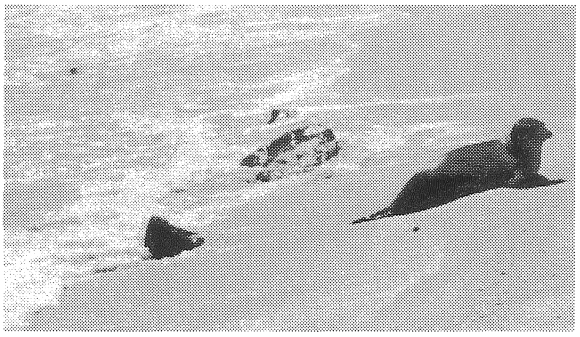
*'Ōpe'*ape'a

Hawaii's lone endemic terrestrial mammal, the 'ōpe'ape'a has been recorded on Kaho'olawe. No studies have been conducted to verify the sighting of or to determine the population. Vegetation restoration and

eradication of rodents and feral cats may result in an increase in insects, which, in turn, will provide additional food resources. A comprehensive baseline survey to determine the current usage of the island by ʻōpeʻapeʻa should be done if funds are available, as should an ongoing monitoring program of their seasonal activities and use of various habitats during the restoration effort.

ʻĪlio holo i ka uaua

photograph 8.3: **Near Lae o Keālaikahiki** (S. Enomoto)



The ʻīlio holo i ka uaua, an endemic mammal of the Hawaiian Islands chain, breeds exclusively in the Northwestern Hawaiian Islands. Human disturbance is a major factor affecting ʻīlio holo i ka uaua, driving them from resting sites and disrupting the mother-pup relationship. Marine debris, such as plastics and fishing net fragments, can be hazardous. Conservation programs on Kahoʻolawe should include evaluating and identifying beaches with the best attributes for use by ʻīlio holo i ka uaua, maintaining written records, and the restriction of human interference on beaches frequented by ʻīlio holo i ka uaua.

Invertebrate

photograph 8.4: **Manduca** (P. Levin)

Introduced predators have either disrupted or caused the extinction of many native invertebrate populations unique to Hawaiʻi. These alien predators include ants, wasps, praying mantids, and some species of flies. The loss of native invertebrate species can alter soil structure composition and interrupt nutrient recycling and pollination of native plants. Their restoration would assist in the natural regeneration of treated areas. It will be difficult, if not impossible, to remove or eradicate the factors which limit endemic invertebrate survival on Kahoʻolawe. The island appears to have widespread and long-established communities of alien ants, wasps, and parasites. Island-wide eradication is probably not a viable option for any

of these species. Instead, attention will be focused on those endemic species of invertebrates currently coexisting within the limitations imposed by a large community of nonindigenous threats. This includes endemic snails, antlions, bees, and wasps. Endemic aquatic invertebrates also deserve special attention.

There are more than 175 species of arthropods identified from Kaho'olawe. The greatest concentration of endemic insects occurs around seasonal or brackish wetlands. At least nine endemic species of aquatic flies have been identified. Wetlands may provide the greatest opportunity for local specialization and differentiation of the Kaho'olawe insect fauna. These invertebrate are important prey for water birds, and should be considered during wetland restoration.

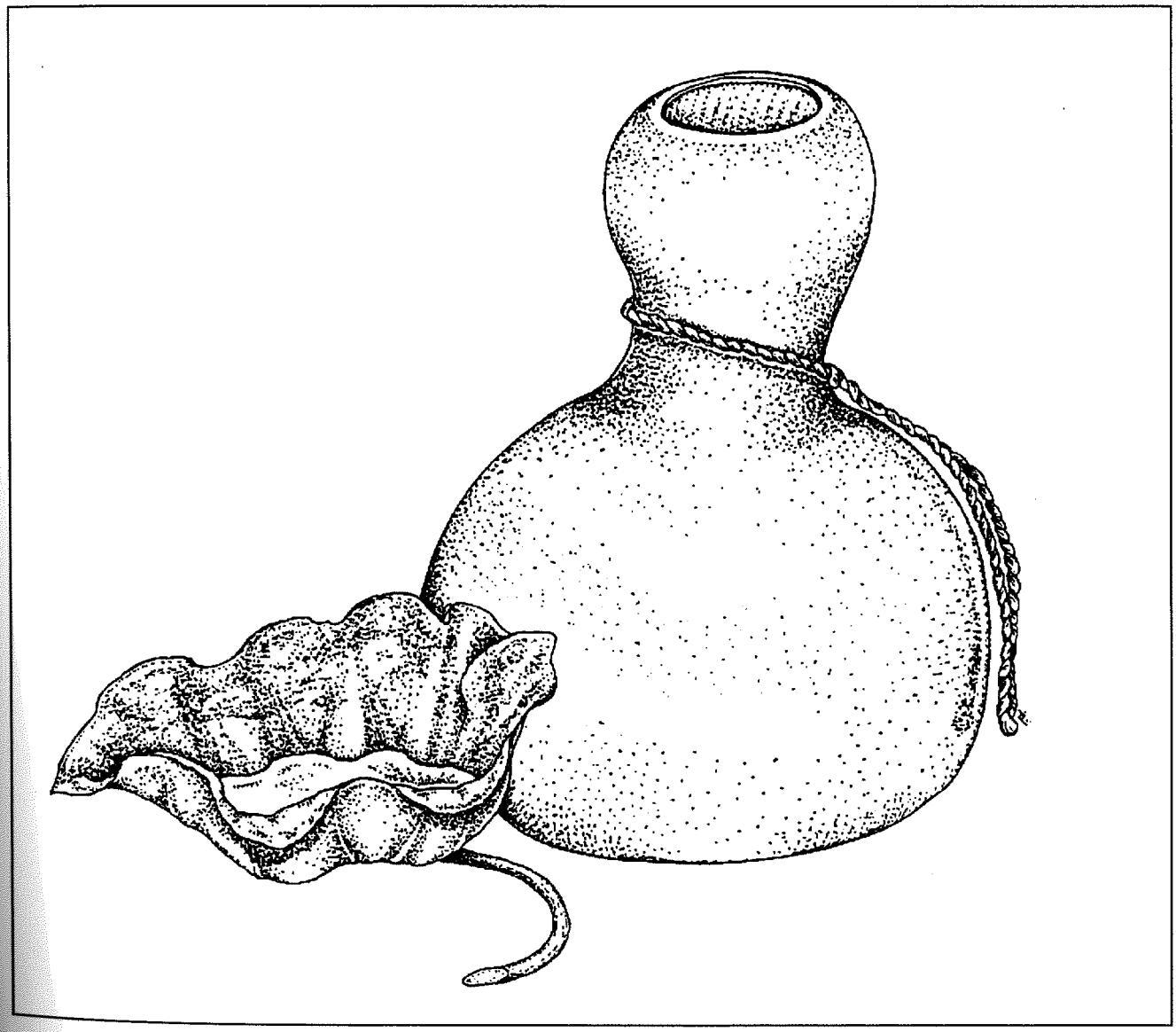
The relative abundance of different arthropod species and their community structure on the island are probably changing in association with the recovery of vegetation, especially with regard to plant-eating insects such as alien moths and butterflies. In addition, observations suggest the existence of well-established populations of many common pollinators found elsewhere in the state. Prominent pollinators include the whitelined sphinx, carpenter bees, and honey bees. The latter are most numerous, visiting a wide range of native and introduced plants. At least one species of endemic yellow-faced bee has been identified. Also, all of the major functional groups of soil and litter invertebrates associated with decomposition of organic matter are present on Kaho'olawe. KIRC will monitor invertebrate populations.

Reptile

Five species of geckos, four species of skinks, and one species of marine turtle have been recorded on Kaho'olawe. There is the possibility of a second species of turtle utilizing the beaches or nearshore waters of the island in the past. Restoration managers should strive to prevent additional alien reptiles from being introduced to the island. The removal of predators may afford a unique opportunity to study the impact that these species have on nesting sea turtles and already established lizard populations.

Avoiding accidental introduction of reptile species not currently present on Kaho'olawe presents the most important management priority for these animals. To accomplish this, preventative quarantine procedures will be instituted.

Restoration Support



Chapter 9

Infrastructure

Infrastructure to support access to the island, transportation across it, water requirements, waste disposal, storage of supplies and equipment, and human shelter will be needed for the environmental restoration and long-term use of Kaho'olawe. The Navy will need the same for the Title X cleanup. Therefore, KIRC and the Navy should cooperate to design and construct infrastructure that serves both the cleanup and the longer-term environmental restoration.

Access to Kaho'olawe

Currently, no reliable, cost-effective method for moving people and materials to Kaho'olawe exists.

Dock at Kūhe'eia

Accessing Kaho'olawe by sea provides the least expensive and most culturally appropriate method to transport people and materials. KIRC will probably construct a small dock at Kūhe'eia for post-cleanup access. This location provides quick and easy access for equipment, materials, and people to the eastern third of the island, and is the island's most protected natural harbor. A floating dock, for example, would not impact the area's reef and would allow for seasonal wave fluctuations. To utilize this harbor, however, the former ranch road from Kūhe'eia to the summit of Lua Makika would have to be reconstructed.

photograph 9.1: **Helicopter Pad at Lua Makika**
(K. Davidson Oh)

Helicopter Landing Pads

Helicopter landing pads allow for rapid response in case of a health,

safety, or environmental (*e.g.*, fire) emergency. Helicopters, though very expensive, also allow for fast and easy delivery of planting materials, people, and supplies to specific, temporary sites. These sites, however, would not use a permanent pad. The existing system should be maintained, but constructing additional landing pads should be limited.

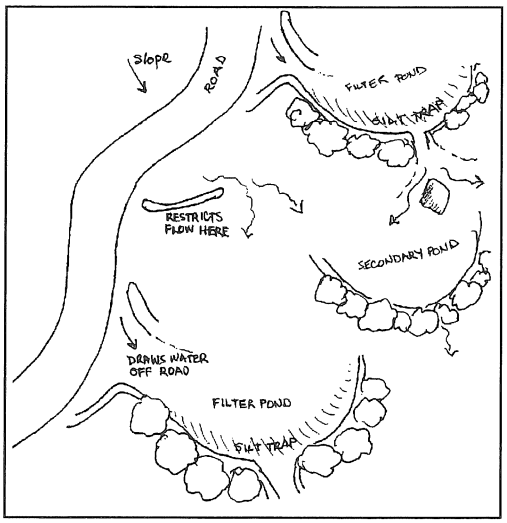
Airplane Landing Strip

Fixed-wing aircraft would provide less expensive access to Kaho'olawe than is currently available, and may be the most cost-effective alternative for movement of cleanup personnel. Light equipment, materials, supplies, and restoration volunteers could be readily transported as well. This mode, however, may not be culturally appropriate or consistent with the long-term vision for Kaho'olawe. Any landing strip should be designed to allow for easy dismantling and revegetation if and when KIRC desires to have it removed.

Roads and Trails

Roads are needed to link the various parts of Kaho'olawe. For the restoration, KIRC should consider improvement and maintenance of Kuamo'o Road (K-1), Halona Road (K-2), Kealaikahiki Road ("rocky road"), and Kūhe'eia Road. Kuamo'o Road (K-1) provides access across the length of the island for a variety of purposes. Halona Road (K-2) allows restoration personnel to get to some of the most severely eroded areas. Kealaikahiki Road provides for access to coastal kīpuka and turtle and seal habitats. Kūhe'eia Road would permit KIRC to utilize Kūhe'eia's natural harbor as the primary access point to the island.

sketch 9.1: Road Construction Technique



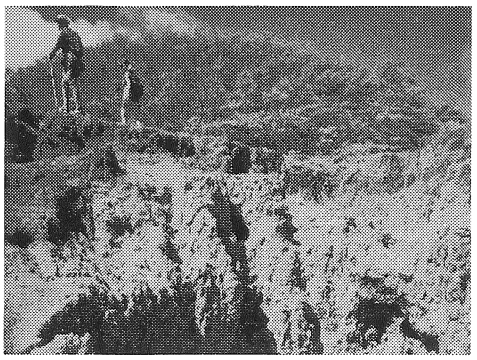
Roads do more than provide vehicular links between two points. They can also serve as water catchments and fire breaks. They could enhance the growth of native plant species, if swales integrated into the roads' design are planted with native plants to provide seeds, seedlings, and cuttings. If existing roads are simply maintained to remain passable, the downstream effects of concentrated runoff will

exacerbate erosion problems. Also, road maintenance will be difficult and expensive. Therefore, sections of Kaho'olawe's existing road network should be rerouted and reengineered to facilitate long-term maintenance, retard flows, and integrate water catchment measures. *Erosion and Run-off Control Standards* will be developed cooperatively between the Navy and KIRC to include recommended design, construction, and maintenance practices to achieve these goals. Possible mechanisms include minimizing cuts, slow speeds, few straight stretches, catchments, vegetative buffers, and carefully designed water crossings.

Trails

In order to access the entire island for restoration work and cultural use, mauka-makai and perimeter trails are identified in the *Kaho'olawe Use Plan*. Trails should incorporate the same design considerations as roads so as to prevent erosion.

photograph 9.2: **Trail between Lua Makika and Lua Keālialuna** (S. Enomoto)



Human Shelter

Much of the cleanup and restoration work currently planned will take place in mauka areas of the eastern third of the island. Staff, volunteers, or possible residents participating in restoration activities on Kaho'olawe will need shelter at one or more base camps for many years to come. These camps should include:

- dormitories, tents and platforms, or residences;
- catchments for potable water;
- composting toilets;
- kitchens or designated cooking areas with a cement pads and solar power;
- mouse-proofed storage facilities;
- solid waste storage and disposal facilities; and
- gardens for food, medicinal, and ceremonial plants.

A camp for use by restoration workers and volunteers will be developed at the kahua ho'omoana site in Lua Makika. KIRC envisions crews of up to fifteen people several times per month once restoration efforts are fully operational. Restoration workers, volunteers, and future residents will

also be based out of kahua kauhale at Honokanai'a, Hakioawa, Kūhe'eia, and Lua Keālialalo.

Water Supply

Probably always dry compared to many other parts of Hawai'i, vegetation and soil loss, surface winds, increased runoff, and alien plant introduction have significantly decreased the availability of water. As the island heals and regenerates, moisture will return to the land. Ecosystem restoration, however, must begin *before* the regeneration of water sources. The current lack of water presents one of the biggest challenges to achieving the restoration goals for Kaho'olawe. To irrigate the number of plants required to revegetate only a small portion of the hardpan will require millions of gallons of water each year at a tremendous financial cost.

This plan makes several assumptions about irrigation and other water demand. These figures may prove to be too high or too low, and will have to be revised based on field experience. The scale of cleanup, restoration, and cultural activities that will occur will determine water demand. Providing irrigation and drinking water will be expensive, logistically difficult, and in some cases impractical. Hard decisions remain about the amount of money KIRC will spend on securing adequate potable and irrigation water. Conservation of potable and non-drinkable water will be vital.

Water Demand

NURSERY. KIRC will operate a plant propagation facility on Maui and nursery-holding facilities on Kaho'olawe. Kaho'olawe's nursery is estimated to demand roughly 500,000 gallons annually for the propagation of mulch crops, seed source, and seedlings for critical erosion areas. Holding facilities may require upwards of 20,000 gallons. The historic ranch cistern, suggested for supplying water to the nursery, may hold up to 400,000 gallons. Assuming adequate rainfall, an effective means to remove sediments from the runoff, and an ability to store water through the dry season, the ranch cistern above Honokanai'a may be able to meet the demands of the nursery.

HUMAN CONSUMPTION. Potable (or, "drinkable") water demand for staff and volunteers is probably lower than the sixty gallons/day/person projected for cleanup personnel by the Navy's *Kaho'olawe Island Water*

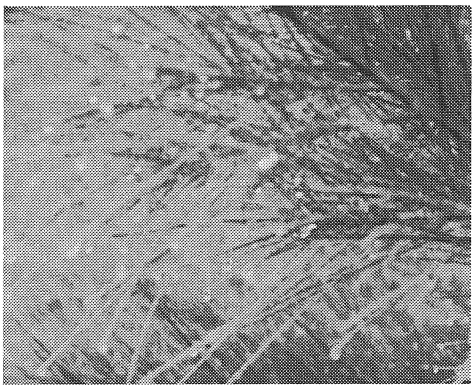
Supply study. During Protect Kaho'olawe 'Ohana access periods, for example, visitors bring their drinking water – less than two gallons/person/day, supplemented by a small catchment system at Hakioawa and salt water from the ocean for bathing. During short-term trips, staff and volunteers would require a minimum of ten gallons per person per day. People living on Kaho'olawe for longer periods would demand an estimated thirty gallons per day.

IRRIGATION. Initial revegetation efforts will focus on dryland plants that can survive and reproduce on Kaho'olawe. Their survival rate with no irrigation will be tested during the 1998 dry season. At a minimum, restoration managers will water at the time of planting. KIRC estimates the total annual water required for one acre of outplanting to be 64,000 gallons.

Sources of Water

FOG AND DEW CAPTURE. KIRC will investigate small-scale collection and storage of fog drip, although the island may be too low for optimum utilization of this technique. At the summit of Lua Makika, significant amounts of dew gather each night on existing plants and soil surfaces. Rock mulching, a traditional Hawaiian planting strategy, captures dew and fog, "sweats" water, and cools plants.

photograph 9.3: **Dew** (S. Enomoto)



GROUNDWATER. The island's basal lens is currently too salty for use. electric resistivity testing suggests the presence of a small, dike-impounded aquifer in the island's center, but of unknown quality and quantity. It is believed the high rainwater runoff and low recharge rates makes neither the lens nor the aquifer useable at the present time. Well development is also expensive. Over time, restored native vegetation will capture atmospheric and surface moisture (*i.e.*, fog and dew) and reduce surface runoff during rains. This, in turn, will facilitate aquifer replenishment, making well development possibly feasible in the future.

photograph 9.4: **Cistern Remnants above Honokanai'a** (S. Enomoto)

SURFACE COLLECTION. Surface runoff from the hardpan is estimated in the tens of billions of gallons. Exposed soils and high levels of sediment make it impractical for catchment and use. Without sealing, covering, or revegetating the hardpan surface, sediment removal from surface runoff would overload any filter system currently available. The repair and use of the former ranch cistern will face these challenges.

RAIN CATCHMENT. Kaho'olawe's annual rainfall averages twenty-five inches at Lua Makika and ten inches along the coast, yet totals tens of billions of gallons each year. Water necessary for successful outplanting is available. The difficulty and expense, however, are in constructing catchment surfaces, storage structures, and distribution systems. One option is an aboveground rain shed, built at the summit of Lua Makika with a metal catchment surface and wood frame. If the frame were to be constructed with sufficient height, holding tanks (23,000 gallons each) could be placed underneath the catchment. The covered area could also serve multiple functions of storage for restoration equipment and supplies, as well as shelter for restoration workers. Constructing the frame only a few feet off the ground would cost significantly less. Each acre of catchment could provide 537,000 gallons of water annually, assuming twenty inches of rain. To water 150 acres of outplanting, a total of fifteen modules would be required to supply 4 million gallons of water each year.

This water could be used for human consumption, if treated. Filter systems can produce five to six gallons per minute, thereby meeting the needs of 100 people per day. Rooftop catchment systems for potable water will be developed for all buildings constructed.

DESALINATION. Small-scale desalinization units produce four to six gallons per hour, and will be used in coastal kahua kauhale. The operating expense and small capacity (300 gallons per day) make them an impractical source for irrigation water. They will be used primarily to supply drinking water in coastal camps. An additional, larger unit at Honokanai'a can produce 9,000 gallons per day.

IMPORTATION. Importing water by boat or pipe from is logistically and financially impractical.

Storing Water

Assuming most irrigation water will be rain catchment, storage will be most efficiently provided near catchment surfaces at Lua Makika. UV-resistant, fiberglass, prefabricated tanks will be used. Some site preparation, including UXO removal, will be required prior to tank installation.

At various outplanting sites and kahua kauhale, KIRC may place a series of small tanks. This moveable, decentralized system will give KIRC greater flexibility in its watering strategy.

Distribution of Water

Moveable, flexible pipe could deliver water from a centralized Lua Makika catchment and storage to smaller tanks in areas around the top and southeast slope of Lua Makika and Pu'u Mōiwi. A series of flexible pipes could distribute irrigation water from these smaller tanks to dispersed outplanting sites.

Botanical Nurseries

KIRC will work with a network of plant propagation centers, volunteers, and specialists to build a capacity to propagate native plants, and to collect their seeds, in the volume required for erosion control and botanical restoration. Certification procedures for nurseries and planting timetables need to be developed so community members can propagate viable plants. Existing private nurseries may be involved on a contract or volunteer basis to provide additional planting materials. As with other aspects of the restoration process, developing the capacity to meet the needs of the restoration will take several years.

Off-Island Nurseries

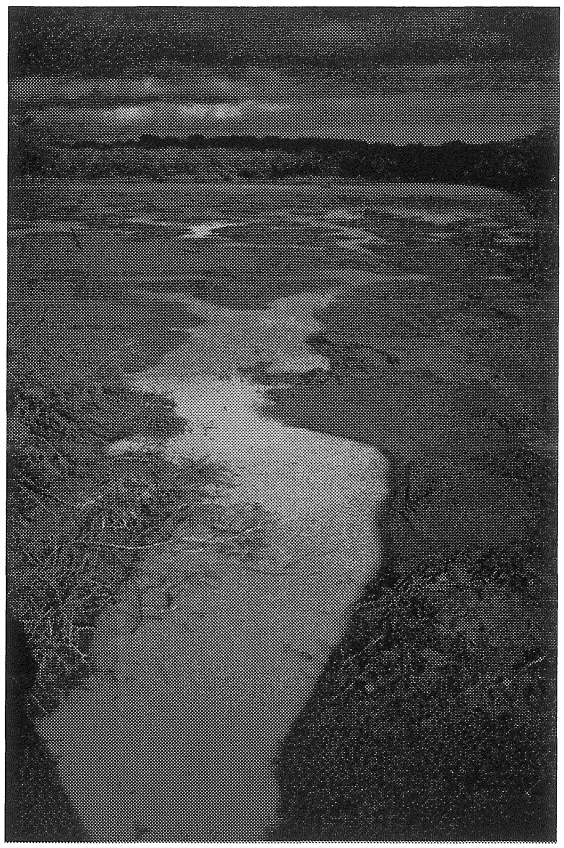
KIRC will establish a nursery on Maui. Initially, seeds and cuttings will come from either the USDA Natural Resources Conservation Service's Plant Materials Center on Moloka'i, or from collections by staff and

volunteers. Later, KIRC will develop its own seed source at the Maui nursery. While initially the nursery will propagate 10,000 plants annually, the capacity will have to be expanded to meet KIRC restoration goals. In addition to growing tables, this facility requires space and equipment to process and store seeds. The nursery also needs a secure area for tools and planting supplies.

Kaho'olawe Nursery and Holding Facilities

A nursery and holding facility on Kaho'olawe will be for additional propagation. Also, plants and seeds arriving from other islands may require some protection from the wind and sun before being planted. These holding facilities can provide quarantine screening to aid in preventing the spread or introduction of pests and disease.

photograph 9.5: **Ponding at Lua Keālialalo** (S. Enomoto)



Chapter 10

Staffing and Community Participation

People are needed to implement this plan and restore life to Kaho'olawe. KIRC has to ensure that its staff, volunteers, and potential future residents understand and support the cultural and spiritual underpinnings of the island's restoration. It is important that those in leadership positions set the example and continue to educate others on a cultural and spiritual approach to restoration. KIRC will develop a cultural orientation for workers and volunteers, and will make a conscious effort to integrate appropriate cultural practices with restoration activities.

Restoration Staffing Requirements

This plan outlines an ambitious and complex restoration effort aimed at mitigating erosion, restoring native vegetation, controlling pests and disease, and restoring native animal populations. Staff and volunteer support will be required for:

- designing erosion control plans for specific sites;
- gathering and propagating native plants;
- obtaining mulch and fertilizer;
- inspecting plants for diseases and insects;
- planning and implementing a fire control program;
- transporting plants, equipment, and workers to and about the island;
- preparing sites for planting;
- planting and watering plants;
- developing and maintaining water systems;
- organizing volunteers and managing contracts;
- establishing a management information system;
- setting up an ecological monitoring system; and
- conducting plant and animal surveys.

KIRC will probably need seven full-time restoration positions as the unexploded ordnance cleanup progresses and greater access to larger areas for environmental restoration activities becomes possible. The proposed positions are as follows:

- **Restoration Ecologist** (existing position) will serve as the overall coordinator for the restoration program, implement this plan, ensure coordination between KIRC's program and the Navy's clearance and environmental restoration activities, and integrate restoration activities with KIRC's other programs.
- **Volunteer Coordinator** will recruit and coordinate volunteers, including the planning and logistics for various volunteer activities on and off Kaho'olawe. (See discussion below.)
- **Restoration Technician II** (two positions) will maintain equipment and planting areas and supervise other workers and volunteers.
- **Restoration Technician I** (three positions) will assist Field Technician IIs, Volunteer Coordinator, and Restoration Ecologist in their duties.

Contracts and Cooperative Agreements

Some restoration needs cannot be met with volunteers or staff. KIRC will develop contracts and cooperative agreements with private companies, individuals, government agencies, and non-profit organizations.

Contracts With Private Firms and Individuals

The private sector can provide many of the goods and services required to implement this plan. The cleanup and restoration of Kaho'olawe will provide new business opportunities and increase the technical capability of local firms. Demand for technical expertise in environmental restoration is growing around the world, and KIRC can foster the development of Hawai'i-based expertise in the field by contracting local firms.

Cooperative Agreements with Federal and State Agencies and Private Voluntary Organizations

Cooperative agreements with the USDA Natural Resources Conservation Service, the USGS Pacific Islands Ecological Research Center, and the University of Hawai'i were instrumental in developing this document. KIRC can secure technical assistance from federal and state agencies for a fraction of the cost of private sector expertise. For the implementation of this plan, KIRC will employ arrangements for technical assistance from other state and federal government agencies and private organizations on the development and testing of restoration methods.

Collaboration with the Protect Kaho'olawe 'Ohana

The Protect Kaho'olawe 'Ohana (PKO) has a long association with the island, experience in restoration work, and a very successful cultural program of public access. The PKO continues to access Kaho'olawe under the authorization of the PKO-Navy Consent Decree. The restoration of Kaho'olawe will be well served by a contract, cooperative agreement, or some other arrangement through which the PKO and its access participants can continue the Hakioawa restoration project, and assist the Kaho'olawe Island Reserve Commission with broader restoration activities.

Volunteer Program

Developing a small staff to organize volunteer projects, will ensure that valuable human and financial resources are not wasted and that progress toward meeting the restoration goals continues for many years. By utilizing volunteer labor to implement restoration projects much can be accomplished at a relatively modest cost.

photograph 10.1: **Volunteer at Lua Makika** (P. Levin)

Projects

The volunteer program envisioned consists of restoration projects of limited duration managed by volunteers, as well as volunteer assistance to KIRC-managed projects. Other volunteer activities could include:

- creating an educational curriculum to involve students;
- identifying seed collection sites;
- collecting seeds and other planting material;
- assisting KIRC with native plant collection, growing, and storage facility on Maui;
- organizing "special event" projects; and
- establishing and coordinating a central fundraising-grant writing committee.

To implement these and future projects, KIRC will commit staff resources to guide and support the volunteer program. Therefore, KIRC must provide necessary cultural orientation, logistical support and supplies, address liability issues, celebrate successes, and recognize volunteers regularly and creatively. Ideally, as promising volunteers become more familiar with the different aspects involved in restoration, they can begin to take on organizational and management responsibilities necessary to continue restoration efforts.

Coordinator

To sustain and facilitate a successful volunteer program, a volunteer coordinator staff position would facilitate the identification, planning, and implementation of volunteer projects. The volunteer coordinator will coordinate and provide logistical support to volunteer leaders, and offer opportunities for feedback on the progress of projects. The coordinator will facilitate communication among volunteers, and between volunteers and KIRC staff and Commissioners, using mechanisms such as newsletters and a web page on the internet.

Restoration Advisory Group

KIRC will establish a Restoration Advisory Group, comprised of technical and cultural advisors to assist in implementing *Ho'ōla Hou I Ke Kino O Kanaloa*. Members should include plant propagators, natural resources managers, and cultural practitioners with traditional ecological knowledge.

Chapter 11

Monitoring and Evaluation

The success of restoration efforts by the Kaho'olawe Island Reserve Commission (KIRC) will depend heavily on its ability to understand the complexities of the island's constantly changing environment, and to modify and adapt restoration plans based on that understanding. Monitoring and evaluation will provide a picture of how Kaho'olawe is changing and whether ecosystems on the island are evolving toward those envisioned by KIRC. Monitoring and evaluation can gauge the success of specific erosion and pest control and revegetation treatments. Relevant and consistent benchmarks will provide the KIRC with an understanding of what to expect over time. This information will benefit other dryland restoration projects in Hawai'i and around the world.

The restoration processes will span many years, involving numerous individuals and organizations. There is a need to maintain a collective body of knowledge. In order to make the information accessible and useful to restoration managers, an integrated information management system is required. KIRC staff will develop protocols and methods for gathering information, working closely with the Navy to insure systematic, timely, and consistent data collection.

Baseline Information

The Kaho'olawe Island Reserve Commission will need baseline information to provide a picture of existing conditions, against which to measure change. Information may include the following.

Cultural and Archaeological Sites

Geographic information system layers developed by KIRC show the general location of sites on the island. The Navy will conduct archaeological surveys prior to clearing ordnance, provide the results to KIRC for incorporation into the KIRC's geographic information system.

Climate

An analysis rainfall information is needed, and a program for systematic gathering of climactic information will be developed. Data are needed on cloud fog and dew patterns and volumes, temperature, humidity and other weather conditions. Additional weather monitoring stations should also be developed to gather information on climatic differences in restored areas.

Water and Soil Runoff

Information on rain amounts and patterns, sediment loads in streams and coastal waters will be the primary components of this baseline dataset. A stream gauge has been installed at Hakioawa but needs recalibration and repair. Additional gauges should also be used in conjunction with erosion control and revegetation activities.

Monitoring existing levels of erosion on Kaho'olawe will be necessary for the planning and implementation of erosion control activities and to determine their success or failure. The Protect Kaho'olawe 'Ohana installed a "pin" system to measure vertical erosion at several sites on the island and data from those points should be incorporated into the pool of baseline knowledge, and used as future measuring sites. Dimensional measurements are also needed in critical gullies mauka from important cultural and use sites and below erosion control and revegetated areas.

Soil Condition and Ecology

Kaho'olawe's soils are undoubtedly lacking in nitrogen, phosphorous, sulfur, and other vital trace elements as well as *mycorrihizal* fungi, *rhizosphere* (root zone) bacteria, and other soil organisms. In order to facilitate the development of self-sustaining native ecosystems through proper soil conditioning and plant treatment, baseline information in areas designated for revegetation will be needed. Initial soil analyses will be conducted just prior to the initiation of restoration activities. Information on soil moisture and composition is also needed, which includes organic matter and the presence of soil decomposers (*mycorrihizal* fungi, bacteria, insects, and other soil organisms). Automated monitoring instruments are available, and could be set up in conjunction with the three existing weather-monitoring stations. Measurements should be taken at three depths for each station.

Vegetative Cover

photograph 11.1: **Transect at NHPS**
(A. Chun Smith)

KIRC needs to integrate aerial photographs taken in 1992 into their geographic information system. The landscape has changed since 1992, however, requiring updated geographic information maps and an assessment of vegetative cover. For effective decision-making, KIRC staff will require useable, small-scale satellite imagery or new aerial photographs of Kaho'olawe.

A survey of alien and native vegetation is necessary to measure future changes in ecosystem composition, and to track the expansion or reduction of alien species populations and native plant kīpuka. This can be done by aerial photographs or transect mapping, and provides the baseline for developing revegetation and fire control programs.

Fauna

Baseline surveys are needed on faunal populations (both native and alien), in order to determine the state of the problem and assess the feasibility of pest eradication. Perhaps the most destructive group of non-indigenous invertebrates is ants, and a thorough survey of the distribution of ants on the island should be done before restoration begins. KIRC is considering feral cat eradication because they pose a major threat to native plant and bird populations. Baseline surveys of feral cat and bird populations are needed for KIRC to evaluate the cost and feasibility of a cat eradication program. There is also a clear need to conduct standardized surveys of Kaho'olawe to document the presence, abundance, and distribution of terrestrial herpetofaunal species. Though the lizards found on the island are likely introductions to Hawai'i, monitoring their response to predator removal may provide important insights into community ecology.

Monitoring Restoration Activities

The above-mentioned baseline information provides the basis against which to measure this change and any change due to erosion control and

revegetation efforts. Each of the datasets outlined above should be monitored at regular intervals. Additional monitoring should be done in relation to specific erosion control and revegetation strategies at selected sites.

Long-Term Monitoring Sites

A system of long-term monitoring sites should be established to provide information about changes in soils and plant and animal populations on Kaho'olawe. These sites should include the remnant soil areas remaining on the island and areas earmarked for ordnance cleanup and environmental restoration. At each site, photographs should be taken, plant species counts made, and rodent and insect traps set. Data from these monitoring areas and other datasets will provide a picture of changing conditions on the island.

Plant Propagation and Seed Collection

When propagating native plants for Kaho'olawe, the procedures employed should be documented and the results evaluated. This information will become a valuable resource. Records kept by staff and volunteers regarding propagation techniques (*e.g.*, treatments in the nursery, germination and survival rates, and on-island planting methods) will increase this field of knowledge considerably. Mapping and monitoring of seed collection sites is also important to maintain a sustainable propagule source.

Erosion Control

Site conditions and erosion control methods used should be documented and monitored. Erosion control documentation should include

- site analysis,
- placement of erosion control measures,
- soil treatment specifics,
- rates of revegetation,
- amount of sedimentation trapped,
- growth or decline in size or length of erosion features, and
- soil moisture levels.

Initially, sites should be monitored monthly and following any rainfall event, with longer intervals after the first six months. Annual transect surveys should be conducted across designated sample areas to determine how well revegetation is proceeding in untreated and treated sites.

Soil Conditions and Plant Growth

Soil conditions and outplantings should be systematically documented and evaluated throughout the restoration process. Monitoring plants on Kaho'olawe will cover, among other things, survival rates, plant health, watering sources and regimes, and production of viable seed. Soil condition information should encompass soil treatments such as fertilizer, mulch, and tilling regimes. Monitoring for soil conditions can occur at the same time as plant monitoring, and can also document changes in the surrounding environment.

Water Catchment and Use

KIRC will have to evaluate the costs of water supply systems. Water catchment and use will be constantly and systematically monitored along with rainfall, dew, soil moisture, and seedling survival rates.

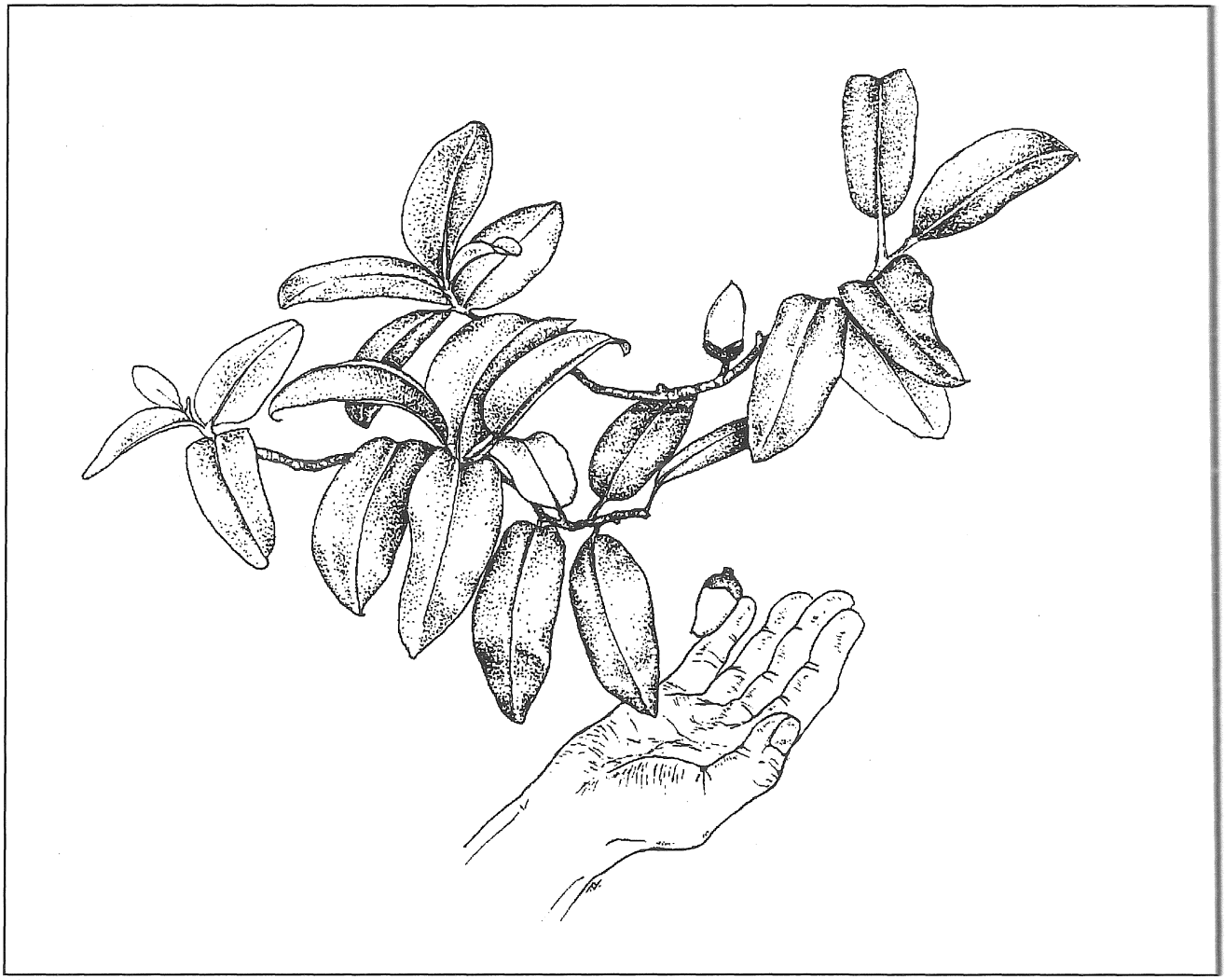
Management, Analysis, and Use of Information

The baseline, monitoring, and evaluation information discussed in this chapter will have to be effectively compiled, stored, and analyzed for an adaptive restoration management strategy to be successful. KIRC staff will be the primary users of the information. KIRC will develop protocols for access and use by restoration managers and others interested in the restoration efforts on the island.

The first step in developing an effective information management system is to revise the existing geographic information system layers. A rudimentary geographic information system has been developed for the Kaho'olawe Island Reserve Commission (KIRC) during the restoration planning process. Many of the data layers used to develop this *Environmental Restoration Plan*, however, are outdated and contain inconsistencies and inaccuracies. These must be updated and corrected before they can be used for restoration management.

The Navy will gather a great deal of information on Kaho'olawe during the UXO cleanup. The Navy's geographic information system sill contain a tremendous amount of information of the island environment and will be useful for monitoring changes on Kaho'olawe, and for restoration planning and implementation. Data in the Navy's geographic information system should be translated into a compatible format and incorporated into KIRC's geographic information system.

Restoration Implementation



Chapter 12

Implementation

Annual Cycle

KIRC's annual restoration cycle will begin in July when budgeting and planning for erosion control and revegetation activities for the year are finalized. This section outlines the types of activities that take place during the phases of that cycle.

July-August

- Select erosion control and revegetation sites.
- Conduct ecological and archaeology site surveys.
- Develop plans for expanded water catchment and repair existing systems.
- Develop plans for expanding worker accommodations and repair existing camps.
- Propagate planting materials.
- Reexamine erosion control and revegetation plan for the year.
- Water outplantings per dry season program.
- Purchase and transport equipment to Kaho'olawe.
- Monitor and weed planting and erosion control areas.

September-October

- Complete erosion control and revegetation site plans.
- Collect mulch resources.
- Begin site preparation.
- Expand and maintain water system.
- Expand and maintain worker accommodations.
- Transport fertilizer and other supplies to Kaho'olawe.
- Finalize arrangements for transporting plants and restoration workers.
- Purchase food and other supplies to support staff and volunteers and transport to Kaho'olawe.

- Inspect and prepare water catchment systems.
- Water outplantings per dry season program.
- Monitor and weed outplanting and erosion control sites.

November-February

- Transport plants and workers to Kaho'olawe after the first rain.
- Move plants to outplanting sites.
- Move water and supplies to planting areas.
- Install additional mulching and soil moisture retention devices.
- Operate food service, kahua kauhale, and transportation for restoration workers.
- Plant and spread seeds.
- Fertilize and weed planting and seeding areas.
- Inspect and monitor water systems.

March-June

- Retain small on-island crew.
- Monitor and weed outplanting and erosion control sites.
- Water outplantings per dry season program.
- Evaluate erosion control and revegetation efforts.
- Analyze results of environmental monitoring.
- Assess pest damage.
- Draft erosion control and revegetation plan and budget for next year.
- Define infrastructure requirements for next year.
- Define plant and supply requirements for next year.
- Define mulch requirements for next year.

Other Activities

- Collect seeds, seedlings, and plant cuttings.
- Propagate plants.
- Quarantine procedures
- Sponsor community education activities.
- Recruit volunteers.
- Develop an environmental monitoring and information system.
- Implement alien species and fire control measures.

Initial Tasks

Certain restoration activities need to occur during the first two years (1998-2000) to develop infrastructure and lay the foundations for all other work. For each task, plan, or protocol, the cultural aspects must be addressed alongside the technical, logistical, and ecological.

Year 1 (FY 1998-1999)

INFRASTRUCTURE

- Reach agreement with the Navy on transportation, infrastructure to support access to the island, and an adequate road network for restoration activities.
- Design and construct Maui nursery and seed storage facilities to provide plants and seeds for 1998-1999 wet season.
- Design first phase of water catchment system at Lua Makika.
- Design first phase of a restoration worker camp at Lua Makika.
- Design Kaho'olawe nursery, seed and mulch crops, and holding facility.

COMMUNITY INVOLVEMENT AND STAFFING

- Develop and organize community volunteer network.
- Coordinate with KIRC's Remediation Program Field Technicians.

FIELD IMPLEMENTATION

- Select and assess specific sites for 1998-1999 revegetation and erosion control activities and develop site-specific plans.
- Purchase supplies, services, and equipment.
- Identify priority cultural sites for stabilization.
- Reach agreement with the Navy to adopt *Runoff and Erosion Control Standards* .
- Explore options for gathering and storing on-island mulch materials.
- Draft *Lua Makika Planting Plan*, incorporating guidelines for controlling fire and alien species.
- Identify plant material source sites and collection times.
- Collect seeds, seedlings, and cuttings.
- Enter into agreement with the Natural Resources Conservation Service for seed collection and plant propagation.
- Initiate alien species control projects.
- Identify of-island nurseries; certify growers; and inspect propagation sites.

MONITORING AND DATA MANAGEMENT

- Develop geographic information system and train KIRC staff.
- Purchase weather and soil condition monitoring equipment.
- Collect baseline information.
- Write relevant monitoring and evaluation procedures.
- Identify key entry points for pests and establish quarantine procedures.

Year 2 (FY 1999-2000)

INFRASTRUCTURE

- Construct first phase of water catchment system at Lua Makika.
- Construct first phase of a restoration worker camp at Lua Makika.
- Construct Kaho'olawe nursery, seed and mulch crops, and holding facility.

FIELD IMPLEMENTATION

- Start site preparation.
- Begin restoration activities, focusing on the summit of Lua Makika.

MONITORING AND DATA MANAGEMENT

- Begin monitoring (*e.g.*, climate, soil, vegetation, and water).
- Conduct a limited faunal survey and monitoring program.

Other Tasks

- Gather traditional ecological knowledge.
- Develop cultural and archaeological protocols.
- Draft *Fire Atlas* and *Fire Management Plan*.
- Conduct a rodent survey and decide on a control program.
- Continue alien plant species eradication and control.
- Establish native species landscaping and gardens around kahua kauhale.
- Explore conversion of kiawe-buffelgrass savanna to native ecosystems.

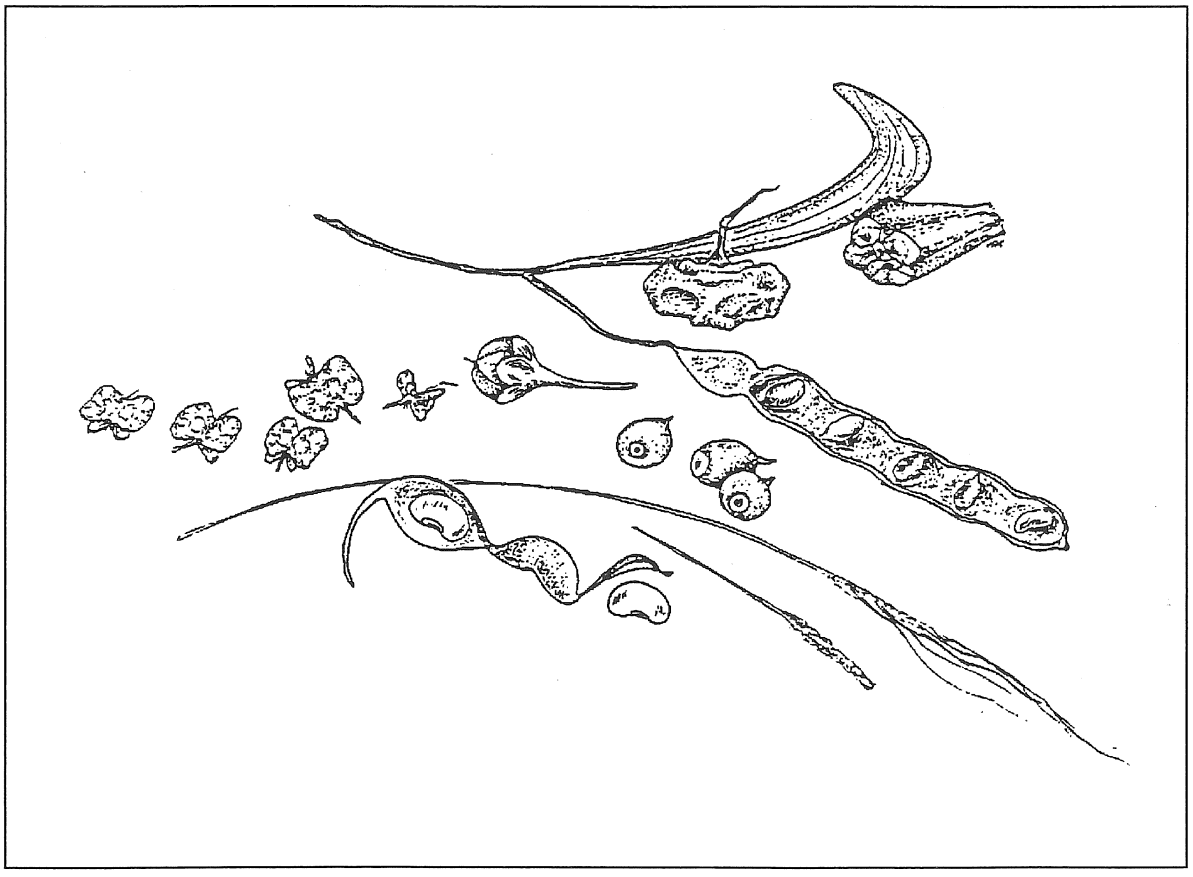
Budget Considerations

Many trade-offs will need to be addressed as this restoration plan is implemented. As decision-makers determine funding commitments, these

trade-offs will become more apparent. Budgetary considerations demand that KIRC selects strategic points within the revegetation planting strategy to serve as catalysts to the natural healing process, whereby the revegetated areas spread, and eventually cover a greater proportion of the island. These concerns highlight the critical need to effectively coordinate with the Navy cleanup operation in order to install basic infrastructure and accomplish other restoration objectives through innovative and complementary implementation of the unexploded ordnance remediation program.

photograph 12.1: Boulder staircase (K. Fairbanks)

Appendices



Appendix 1: Native and Polynesian Flora Species Currently Found on Kaho'olawe

Hawaiian Name	*English Name*	*Latin Name*
Tree		
hala	pandanus, screw pine	*Pandanus ordoratissimus*
kukui	candlenut	*Aleurites moluccana*
nena	seaside heliotrope	*Heliotropium curassavicum*
wiliwili		*Erythrina sandwicensis*
Shrub		
'akoko, koko, kokomalei		*Chamaesyce celastroides* var. *amplectens* and var. *stokesii*
kolomona, uhiuhi		*Senna gaudichaudii*
ko'oloa kea	hoary abutilon	*Abutilon incanum*
ko'oko'olau		*Bidens mauiensis*
'ilima		*Sida fallax*
maiapilo, pua pilo		*Capparis sandwichiana*
ma'o	Hawaiian cotton	*Gossypium tomentosum*
naio		*Myoporum sandwicense*
naupaka kahakai	beach naupaka	*Scaevola sericea*
'ohai		*Sesbania tomentosa*
palupalu Kanaloa		*Kanaloa Kahoolawensis*
Herb		
'ākoko	spurge, prostrate	*Chamaesyce skottsbergii* var. *vaccinioides*
'ākulikuli	sea purslane	*Sesuvium portulacastrum*
alena		*Boerhavia glabrata , B. herbstii , B. repens*
'ihi		*Portulaca molokiniensis , P. villosa*

Appendix 1 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Herb (continued)		
nehe		*Lipochaeta brynaii , L. integrifolia , L. lavarum , L. rockii , L. succulenta*
nohu		*Tribulus cistoides*
ʻohelo kai, ʻaeʻae		*Lycium sandwicense*
popolo	glossy nightshade	*Solanum americanum*
puakala		*Argemone glauca*
ʻuhaloa, hiʻaloa		*Waltheria indica*
		Cressa truxillensis
Fern		
kumuniu		*Doryopteris decipiens*
pololei		*Ophioglossum concinnum*
		Asplenium adiantum-nigrum
Vine		
ʻanunu, kupala		*Sicyos pachycarpus*
koali ʻai	ivy-leaved morning glory	*Ipomoea cairica*
koali ʻawa, koali ʻawahia		*Ipomoea indica*
koali pehu	Hawaiian moonflower	*Ipomoea tuboides*
pāʻū o Hiʻiaka		*Jacquemontia ovalifolia* subsp. *Sandwicensis*
pōhuehue	beach morning glory	*Ipomoea pes-caprae*
	hairy merremia	*Merremia aegyptia*

Appendix 1 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Vine (continued)		
		Vigna o-wahuensis
Grass and Sedge		
ʻakiʻaki		*Sporobolus virginicus*
kāwelu, ʻemoloa		*Eragrostis variabilis*
kakonakona		*Panicum torridum , P. xerophilum*
pili	twisted beardgrass	*Heteropogon contortus*
		Carex meyenii
		Eleocharis calva
		Eragrostis atropioides
		Mariscus phoeoides spp. *Phleoides*
		Panicum fauriei var. *fauriei; P. fauriei* var. *latius*
		Panicum ramosium

Appendix 2: Native and Polynesian Flora Species from Previous Planting Trials on Kaho'olawe

Hawaiian Name	*English Name*	*Latin Name*
Tree		
halapepe		*Pleomele aurea*
hau	hibiscus	*Hibiscus tiliaceus*
'iliahi	sandalwood	*Santalum ellipticum*
kamani		*Calophyllum inophylium*
kauila		*Alphitonia ponderosa*
koa		*Acacia koa*
koai'a or koai'e		*Acacia koaia*
kou		*Cordia subcordata*
lama		*Diospyros sandwicensis*
māmane		*Sophora chrysophylla*
milo		*Thespesia populnea*
niu	coconut	*Cocos nucifera*
'ōhi'a		*Metrosideros polymorpha; M. tremuloides*
olonā		*Touchardia latifolia*
Shrub		
'a'ali'i		*Dodonaea viscosa*
alahe'e		*Canthium odoratum*
'ānapanapa	Hawaiian soap plant	*Colubrina asiatica*
'anaunau, naunau, kunana		*Lepidium bidentatum*
'āweoweo or 'āheahea		*Chenopodium oahuense*
'ilie'e		*Plumbago zeylanica*
kī		*Cordyline terminalis*
ko'oloa 'ula		*Abutilon menziesii*
kulu'i		*Nototrichium sandwicense*
ma'aloa, ma'oloa, 'oloa		*Neraudia sericea*

Appendix 2 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Shrub (continued)		
ma'o hau hele		*Hibiscus brackenridgei*
noni		*Morinda citrifolia*
pōhinahina	beach vitex	*Vitex rotundifolia*
'ūlei		*Osteomeles anthyllidifolia*
		Gouania hillebrandii
Herb		
hinahina		*Artemisia australis*
hulumoa, kaumahana		*Exocarpus gaudichaudii*
Grass		
'ahu'awa		*Mariscus javanicus*
	Hilo Ischaemum	*Ischaemum byrone*
	stargrass	*Cynodon plectostachyus*
		Eragrostis atropioides

Appendix 3: Native Species Recommended for the Revegetation of Kaho'olawe

Hawaiian	*Latin*	*Source*	*Growing Ease*	*Growing Medium*	*Erosion Control*
Trees					
'ahakea	*Bobea sandwicensis; B. timonioides*	Maui Nui	medium	seed	
a'ia'i	*Streblus pendulinus*	WM, EM	medium	seed	
'aiea	*Nothocestrum latifolium*	W La	difficult	seed	
'akoko	*Chamaesyce stokesii*	Olowalu (WM)	medium	seed, cutting	
'āla'a	*Pouteria sandwicensis*	EM, W La	medium	seed	
alahe'e	*Canthium odoratum*	EM, WM, W La	easy	seed	
'ānapanapa	*Colubrina asiatica*	Maui Nui	medium	seed	
hala	*Pandanus odoratissimus*	Maui Nui	easy	seed	
halapepe	*Pleomele auwahiensis*	EM, S Mo	medium	seed, cutting	
hao	*Rauvolfia sandwicensis*	EM (Kanaio)	difficult	seed	
hau	*Hibiscus tiliaceus*	Maui Nui	easy	cutting	good
'iliahi	*Santalum freycinetianum*	La	medium	seed	good
keahi	*Nesoluma polynesicum*	W La	medium	seed	
koai'a	*Acacia koaia*	S Mo, La	easy	seed	
kōlea	*Myrsine lanaiensis; M. lessertiana*	W La; Maui Nui	medium; medium	seed; seed	
kou	*Cordia subcordata*	all islands	easy	seed	
kukui	*Aleurites moluccana*	all islands	easy	seed	
kulu'ī	*Nototrichium sandwicense*	Pu'u o Kali	medium	seed, cutting	
Lama	*Diospyros sandwicensis*	WM, W La	easy	seed	
mai'a	*Musa xparadisiaca*	all islands	easy	root suckers	
māmane	*Sophora chrysophylla*	WM, EM	easy	seed	
maua	*Xylosma hawaiiense*	EM, W La	difficult	seed	
mehame	*Antidesma pulvinatum*	Maui Nui	medium	seed	
milo	*Thespesia populnea*	all islands	easy	seed	
nānū	*Gardenia bighamii*	La	medium	seed	
niu	*Cocos nucifera*	all islands	easy	seed	

Appendix 3 (continued)

Hawaiian	*Latin*	*Source*	*Growing Ease*	*Growing Medium*	*Erosion Control*
Trees, continued					
ʻohe makai	*Reynoldsia sandwicensis*	EM, W La	medium	seed	
ʻōhiʻa	*Metrosideros polymorpha*	WM, S Mo, W La	easy	seed, cutting	
olopua	*Nestegis sandwicensis*	W La	difficult	seed	
ʻulu	*Artocarpus altilis*	all islands	medium	suckers	
wiliwili	*Erythrina sandwicensis*	Puʻu o Kali, S Mo	easy	seed	good
Shrubs					
ʻaʻaliʻi	*Dodonaea viscosa*	W La, WM	easy	seed	good
ʻākia	*Wikstroemia uva-ursi; W. oahuensis*	WM, E Mo	easy	seed, cutting	good
ʻakoko	*Chamaesyce celastroides*	La, S Mo, EM, Puʻu o Kali	medium	seed, cutting	good
ʻawa	*Piper methysticum*	EM, WM, Mo	easy	cutting	poor
ʻāweoweo	*Chenopoduim oahuense*	EM, S Mo	easy	seed	good
ʻiliahi aloʻe	*Santalum ellipticum*	Maui Nui	medium	seed	good
ʻilieʻe	*Plumbago zeylanica*	Maui Nui	easy	seed	good
ʻilima	*Sida fallax*	Kah, Maui Nui	easy	seed	good
kī	*Cordyline terminalis*	all islands	easy	cutting	fair
kokio	*Hibiscus kokio*	WM	easy	cutting	poor
kolokolo kahakai	*Vitex rotundifolia*	Maui Nui	easy	seed, cutting	good
kolomona	*Senna gaudichaudii*	Kah, EM	easy	seed	
koʻokoʻolau	*Bidens menziesii; B. molokaiensis*	WM, Mo	easy medium	seed	good
koʻola kea	*Abutilon incanum*	Kah, Maui Nui	medium	seed	good
koʻola ʻula	*Abutilon menziesii*	La	medium	seed	good
kūpaoa	*Dubautia linearis*	EM, WM	easy	seed	good
maiapilo	*Capparis sandwicensis*	EM	easy	seed	good
maʻo	*Gossypium tomentosum*	Kah	easy	seed	good
maʻo hau hele	*Hibiscus brackenridgei*	Puʻu o Kali, La	medium	seed	good

Appendix 3 (continued)

Hawaiian	*Latin*	*Source*	*Growing Ease*	*Growing Medium*	*Erosion Control*
Shrubs, continued					
naio	*Myoporum sandwicensis*	W La, EM	easy	seed	good
naupaka kahakai	*Scaevola sericea*	Maui Nui	easy	seed, cutting	good
naupaka kuahiwi	*Scaevola gaudichaudii*	S Mo	medium	seed	good
nehe	*Lipochaeta integrifolia*	Maui Nui	easy	seed	good
ʻohai	*Sesbania tomentosa*	Kah	easy	seed	good
pūkiawe	*Styphelia tameiameiae*	WM, EM, S Mo	medium	seed	good
ʻūlei	*Osteomeles anthyllidifolia*	M, EM, S Mo, W La	medium	seed, cutting	good
wauke	*Broussonetia papyrifera*	WM, EM, Mo	easy	cutting	fair
Herbs					
ʻākulikuli	*Sesuvium portulacastrum*	Maui Nui	easy	seed, cutting	good
ʻala'ala wainui	*Plectranthus parviflorus*	Maui Nui	easy	seed, cutting	
hinahina	*Heliotropium anomalum* var. *argenteum*		medium	seed, cutting	good
ʻihi	*Portulaca lutea; P. molokiniensis; P. villosa*	Maui Nui; Kah, Molokini; WM, EM	easy	seed, cutting	
kalo	*Colocasia esculenta*	all islands		huli	poor
ʻōhelo kai	*Lycium sandwicensis*	Maui Nui	easy	seed, cutting	good
pāwale	*Rumex giganteus; R. skottsbergii*	EM, Mo; Hawai'i	easy	seed	
puakala	*Argemone glauca*	W Mo, Kah, WM, EM	easy	seed	
ʻuhaloa	*Waltheria indica*	Kah, Maui Nui	easy	seed	good

Appendix 3 (continued)

Hawaiian	*Latin*	*Source*	*Growing Ease*	*Growing Medium*	*Erosion Control*
Vines					
ʻānunu	*Sicyos* spp.	WM, W La	easy	seed	fair
ʻāwikiwiki	*Canavalia pubescens; C. hawaiiensis*	M, EM, S Mo, W La	easy	seed	good
huehue	*Cocculus trilobus*	WM, EM, S Mo, W La	easy	seed	good
hunakai	*Ipomoea imperati; I. tuboides*	Maui Nui; Maui Nui	easy; easy	seed; seed	good; good
kaunaʻoa	*Cuscuta sandwichiana*	Maui Nui	easy	seed	good
koali	*Ipomoea indica*, etc.	Pu`u o Kali, W La, WM	easy	seed	good
koali ʻai	*Ipomoea carica*	Maui Nui	easy	seed	good
kūpala	*Sicyos pachycarpus*	all islands	easy	seed	good
pāʻū o Hiʻiaka	*Jacquemontia ovalifolia*	Maui Nui	easy	seed, cutting	good
pōhuehue	*Ipomoea pes-caprae*	Maui Nui	easy	cutting	good
ʻuala	*Ipomoea batatas*	all islands	easy	seed	good
---	*Bonamia menziesii*	Pu`u o Kali, EM	medium	seed	poor
Ferns					
kalamoho	*Pellaea ternifolia*	EM, Pu'u o Kali	medium	spores	
kīlau	*Pteridium aquilinum*	Maui Nui	easy	clump	good
kumuniu	*Doryopteris* spp.	EM, Pu`u o Kali	medium	spores	
kupukupu	*Nephrolepis exaltata*	all islands	easy	rhizome	
moa	*Psilotum nedum*	all islands	easy	rhizome	
palaʻā	*Sphenomeris chinensis*	Maui Nui	easy	plugs	good

Appendix 3 (continued)

Hawaiian	*Latin*	*Source*	*Growing Ease*	*Growing Medium*	*Erosion Control*
Ferns, continued					
uluhe	*Dicranopteris linearis*	all islands	difficult	rhizome, spores	
Grasses & Sedges					
'aki'aki	*Sporobolus virginicus*	Maui Nui	easy	seed, clump	good
kākonakona	*Panicum* spp.	La	medium	seed	
kāwelu	*Eragrostis variabilis*	WM	medium	seed	good
makaloa	*Cyperus laevigatus*	Maui Nui	easy	seed	
pili	*Heteropogon contortus*	WM, Kah, La	medium	seed	good
---	*Carex wahuensis*	Maui Nui	easy	seed	
---	*Eragrostis atropioides*	WM	easy	seed	
---	*Fimbristylis* spp.	WM	medium	seed	
---	*Gahnia* spp.	WM, EM	medium	seed	good
---	*Mariscus hillebrandii*	WM, EM, La	medium	seed	

Appendix 4:

Reference Ecosystems for Kaho'olawe Revegetation Zones

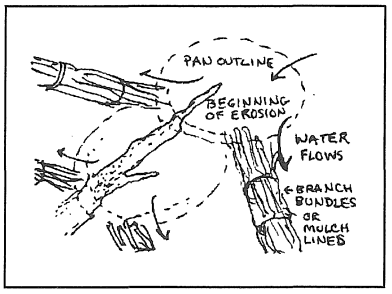
Name of Natural Community	*CO*	*CL*	*DGS*	*DW*	*DF*	*MF*
KAHO'OLAWE COMMUNITIES:						
'Aki'aki Coastal Dry Grassland	X					
Cressa truxillensis Coastal Dry Herbland	X					
Hawaiian Mixed Shrub Coastal Dry Cliff		X				
'Ilima Coastal Dry Shrubland	X		X	X		
Ma'o Coastal Dry Shrubland	X		X	X		
Pili Lowland Dry Grassland			X	X		
MAUI NUI COASTAL COMMUNITIES:						
'Akoko Coastal Dry Shrubland		X	X	X		
'Ākulikuli Kai Coastal Dry Herbland	X					
Dwarf Naupaka Coastal Dry Shrubland	X					
Hinahina Coastal Dry Shrubland	X					
Naio Coastal Dry Shrubland	X		X			
Pōhuehue Coastal Dry Shrubland	X					
MAUI NUI DRY LOWLAND COMMUNITIES:						
'A'ali'i Lowland Dry Shrubland			X	X		
Ko'oko'olau Lowland Dry Shrubland		X	X	X		
Koai'a Lowland Dry Forest				X	X	X
Lama Lowland Dry Forest				X	X	
Lama/Olopua Lowland Dry Forest				X	X	
Wiliwili Lowland Dry Forest				X	X	
MAUI NUI MESIC LOWLAND COMMUNITIES:						
Kāwelu Lowland Mesic Grassland		X	X			
Halapepe Lowland Mesic Forest				X	X	X
Koa/'Ōhi'a Lowland Mesic Forest						X
Lama/'Ōhi'a Lowland Mesic Forest						X
Lāna'i Diverse Lowland Mesic Forest						X
'Ōhi'a Lehua Lowland Mesic Forest						X
'Ulei Lowland Mesic Forest			X	X		

KEY:

CO = coastal
CL = cliff
DGS = dry grassland and shrubland
DW = open canopy woodland
DF = closed canopy dry forest;
MF = closed canopy mesic forest
X = proposed zone of establishment

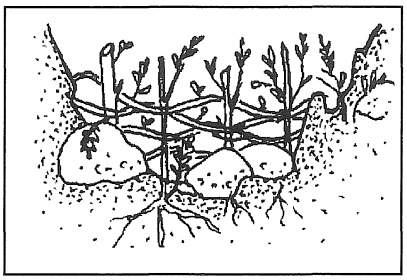
Appendix 5: Erosion Control Structures

sketch A.1: **Use of Wattle at Headcut**



WATTLE. Dead branches, vines, or grasses woven into bundles, wattles catch soil and organic material. Like fascines, wattles must be used alongside water controls in order to mitigate the "flash flood" forces of rain in gullies and to prevent blowouts of other erosion control structures.

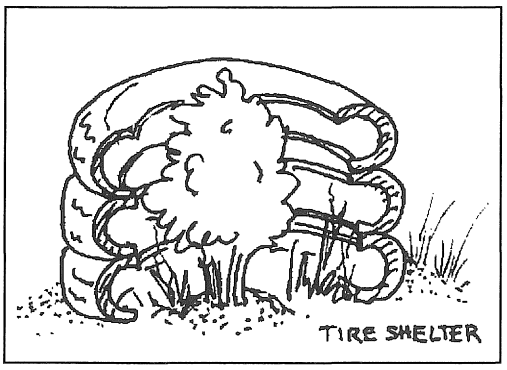
sketch A.2: **Fascine**



FASCINE. Fascines are living vines or grasses woven into bundles, which catch soil or organic material. They must be used within the context of a series of water controls to mitigate the "flash flood" forces of rain in gullies and to prevent blowouts of other erosion control structures.

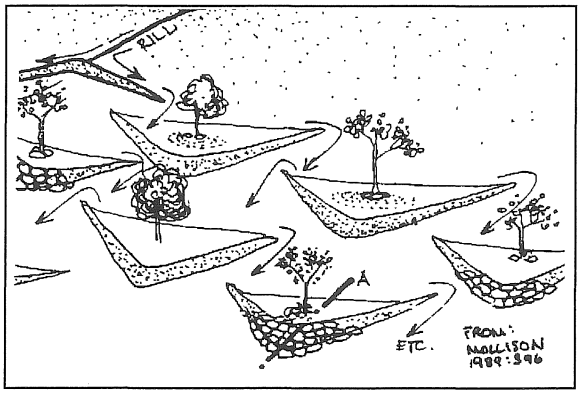
WINDBREAK. On the open hardpan, wind is the most significant factor preventing revegetation. Before beginning large-scale erosion control and revegetation efforts, windbreaks are needed to mitigate the effect of wind upon treated areas. The effected distance behind a windbreak is about ten times its height. A minimum of three feet in windbreak area has been suggested, due to the sheering effect of winds on the hardpan. Both plants and manmade materials may be used. The latter has the advantage of immediate application, but the disadvantages of limited serviceability and removal, as well as acquisition and installation costs.

sketch A.3: **Type of Windbreak Structure**



SWALE. Swales slow, divert, or hold water. When combined with planting, swales enhance water percolation and reduce evaporation. To minimize the need for subsurface clearance, swales on Kaho'olawe may be constructed above the ground by placing branches, mulch, or other material on the surface of the soil. Swale size will vary according to topography and the needs of a site. A series of swales could be placed in a myriad of patterns to address site-specific soil and water capture needs. Swales will be of primary importance of ruse in directing water away from roads.

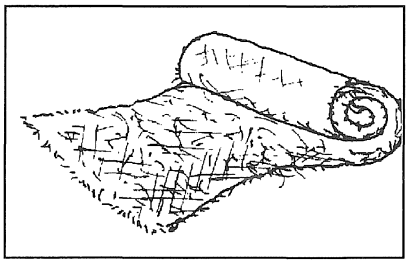
sketch A.4: **"Boomerang" Swales**



BERM. A raised shelf or a dike often used in contour plowing to catch soil and water on slopes. Also, the raised side of a swale is a berm.

GEOTEXTILE. Geotextiles are natural and synthetic fiber materials, often with some form of fine, biodegradable netting. They are used to cover and hold soil, retain moisture, and encourage plats to take root. Not only are geotextiles expensive, but they must be secured into the ground using metal pegs or pins, a problematic task in uncleared areas. Therefore, KIRC will substitute geotextiles on a limited basis where other techniques cannot be used.

sketch A.5: **Geotextile**



CHECK DAM AND GABION. Check dams are permeable barriers built across a gully or waterway to slow or redirect he flow of water and increase sediment capture. They can be constructed from a variety of materials. Gabions are wire baskets filled with rocks, and either used in the construction of check dams or anchored into the side of a gully or streambed to stabilize the slope, slow the water flow, augment infiltration, and increase sediment capture.

Appendix 6:

Alien Flora Species Currently Found on Kaho'olawe

Hawaiian Name	*English Name*	*Latin Name*
Trees		
kiawe	mesquite, algaroba	*Prosopis pallida*
koa haole, ekoa	----	*Leucaena leucocephala*
----	Formosan	*Acacia confusa*
	eucalyptus	*Eucalyptus* spp.
	false kamani, tropical almond	*Terminalia catappa*
	ironwood	
	longleaf,	*Casuarina glauca*
paina	saltmarsh	*Casuarina equisetifolia*
	shortleaf	
	tamarisk, athel	*Tamarix aphylla*
	tobacco, tree	*Nicotiana glauca*
Shrub		
'auhuhu, hola		*Tephrosia purpurea*
hāmākua pāmakani		*Ageratina riparia*
ha'uōī, ōī		*Verbena litoralis*
kaliko		*Euphorbia heterophylla*
	apple of Sodom	*Solanum linnaeanum*
	Arabian coffee	*Coffea arabica*
	beggartick, Spanish needle	*Bidens pilosa*
	beggarweed, Florida	*Desmodium tortuosum*
pā'aila, kolī	castor bean	*Ricinus communis*
kīkānia	cocklebur	*Xanthium strumarium*
puakalaunu	crown flower	*Calotropis gigantea*
	hairy abutilon	*Abutilon grandifolium*
	Indian fleabane	*Pluchea indica*
'inikō	indigo	*Indigofera suffruticosa*
ōī	Jamaica vervain	*Stachytarpheta jamaicensis*
kolu	klu	*Acacia farnesiana*

Appendix 6 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Shrubs, continued		
	lantana	*Lantana camara*
	Mangrove – American, red	*Rhizophora mangle*
	oleander	*Nerium oleander*
	pepperwort, peppergrass	*Lepidium oblongum*
panini	prickly pear	*Opuntia ficus-indica*
	slender mimosa, virgate mimosa	*Desmanthus virgatus*
	sourbush	*Pluchea symphytifolia*
		Bidens alba var. *radiata*
		Cassia spp.
Fern		
kupukupu, ni'ani'au		*Nephrolepis multiflora*
	goldfern	*Pityrogramma calomelanos*
	rough maidenhair	*Adiantum hispidulum*
		Christella dentata
		Christella parasitica
		Phymatosorus scolopendera
Herb		
maile honohono		*Ageratum conyzoides*
	balloon plant	*Asclepias physocarpa*
	basil	*Ocimum gratissimum*
	beggarweed, three-flowered	*Desmodium triflorum*
	bitter herb, European centaury	*Centaurium erythraea*
	bull thistle	*Cirsium vulgare*
laulele	butterfly weed	*Asclepias curassavica*

Appendix 6 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Herbs, continued		
	cat's ear, hairy	*Hypochoeris radicata*
	cat's ear, smooth	*Hypochoeris glabra*
	cheese weed	*Malva parviflora*
	coat buttons	*Tridax procumbens*
	cow pea, wild bean	*Macroptilium lathyroides*
	crown-beard, golden	*Verbesina encelioides*
	crown-beard, small yellow	*Sigesbeckia orientalis*
	false mallow	*Malvastrum coromandelianum*
	Flora's paintbrush	*Emilia sonchifolia*
ilioha	horseweed, hairy	*Conyza bonariensis*
	horseweed	*Conyza canadensis*
	ironweed, little	*Vernonia cinerea*
	Madagascar periwinkle	*Catharanthus roseus*
pakalolo	marijuana	*Cannabis sativa* ssp. *Indica*
	nodeweed	*Synedrella nodiflora*
	ombu, bella sombra	*Phytolacca dioica*
lauki	partridge pea	*Chamaecrista nictitans*
'ākulikuli kai	pickleweed	*Batis maritima*
'ihi	pigweed	*Portulaca oleraca , P. pilosa*
	pigweed, goosefoot	*Chenopodium carinatum*
	prickly lettuce	*Lactuca serriola*
	prickly sida	*Sida spinosa*
	purple cudweed	*Gnaphalium purpureum*
	radish, wild	*Raphanus sativus*
	rattlepod	*Crotalaria incana*
	saltbush	*Atriplex suberecta*
	saltbush, Australian	*Atriplex semibaccata*
	scarlet pimpernel	*Anagallis arvensis*
malina	sisal	*Agave sisalana*
pakai	slender amaranth	*Amaranthus viridis*

Appendix 6 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Herbs, continued		
pualele	sow thistle	*Sonchus oleraceus*
pua pilipili	Spanish clover	*Desmodium sandwicense*
pakai kūkū	spiny amaranth	*Amaranthus spinosus*
pipili	spiny-bur	*Acanthospermum australe*
	spurge, graceful	*Chamaesyce prostrata*
koko kahiki	spurge – hairy, garden	*Chamaesyce hirta*
	star thistle, knapweed	*Centaurea melitensis*
	swinecress	*Coronopus didymus*
	telegraph weed	*Heterotheca grandifolia*
	tomato	*Lycopersicon esculentum*
	tomato, currant	*Lycopersicon pimpinellifolium*
	tumble mustard	*Sisymbrium altissimum*
	tumbleweed, Russian thistle	*Salsola kali*
ʻihi makole	yellow wood sorrel	*Oxalis corniculata*
puapihi	zinnia	*Zinnia peruviana*
		Boerhavia coccinea
		Crassocephalum crepidioides
		Emilia fosbergii
		Galinsoga parviflora
		Macroptilium atropurpureum
		Polycarpon tetraphyllum
Fern		
laua'e		*Phymatosorus scolopendria*
Grass and Sedge		
	Australian bluestem	*Dicanthium sericeum*
	beach wiregrass	*Dactyloctenium aegyptium*

Appendix 6 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Grasses and Sedges, continued		
	bur, bertero goatgrass	*Tragus berteronianus*
	bristly foxtail	*Setaria verticillata*
	buffelgrass	*Cenchrus ciliaris*
	feather finger	*Chloris virgata*
	feathery pennisetum	*Pennisetum polystachion*
manienie	giant Bermuda	*Cynodon dactylon*
	Guinea	*Panicum maximum*
kukaepua'a	Henry's crabgrass	*Digitaria ciliaris*
	Japanese lovegrass	*Eragrostis tenella*
pu'ohe'ohe	Job's tears	*Coix lacryma-jobi*
	jungle rice grass	*Echinochloa colona*
	molasses grass	*Melinis minutiflora*
	Natal redtop	*Rhynchelytrum repens*
	pitted beardgrass	*Bothriochloa pertusa*
	sourgrass	*Digitaria insularis*
	stinkgrass	*Eragrostis cilianensis*
kō	sugar cane	*Saccharum officinarum*
mau'u lei	swollen finger	*Chloris barbata*
	wildergrass	*Dicanthium aristatum*
	wiregrass	*Eleusine indica*
	yellow foxtail	*Setaria gracilis*
		Cenchrus tribuloides
		Chloris truncata
		Chloris spp.
		Eragrostis spp.
Vines		
	balsam pear	*Momordica charantia*
ka'ukama	cucumber	*Cucumis sativus*

Appendix 6 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Vines, continued		
	hedgehog gourd, teasel gourd	*Cucumis dispsaceus*
	night-blooming cereus	*Hylocereus undatus*
liliko'i	passion fruit	*Passiflora edulis*
ipu 'ai maka	watermelon	*Citrullus lantaus*
	tineroo, kokomo	*Glycine wightii*

Appendix 7: Alien Flora Species Used in Previous Planting Trials on Kaho'olawe

Hawaiian Name	*English Name*	*Latin Name*
Trees		
	black cypress pine	*Callitris endlicheri*
	black wattle	*Acacia mearnsii*
	brutis pine	*Pinus brutis*
	eucalyptus	
	compacta	*Eucalyptus globulus* var. *compacta*
	lemongum	*Eucalyptus citriodora*
	redgum	*Eucalyptus tereticornis*
	robusta	*Eucalyptus robusta*
	----	*Eucalyptus punctata*
	----	*Eucalyptus torelliana*
	gyrocarp	*Cyrocorpus americanus*
	heliotrope	*Messerschmidia argentea; Tournefortia argentea*
	redbark ironwood	*Eucalyptus sideroxylon*
	Madagascar olive	*Norohia emarginata*
	mango	*Mangifera indica*
	Mediterranean cypress	*Cupressus sempervirens*
	Murray redgum	*Eucalyptus camaldulensis*
	Murray river pine	*Callitris columellaris*
	oleander, sweet-scented	*Nerium indicum*
	pine	*Callistris calcarata*
	pride of India	*Melia azedarach*
	seagrape	*Cocoloba urifera*
paka	tobacco	*Nicotiana tabacum*
	tree daisy	*Montanoa hibiscifolia*
		Acacia implexa
		Acacia mangium
		Araucaria heterophylla
	seaban	*Sesbania grandiflora*

Appendix 7 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Trees, continued		
	verbena	*Verbena litoralis*
wauke	paper mulberry	*Broussonetia papyrifera*
		Leucena leucocephala
Herbs		
pānini ʻawaʻawa	aloe	*Aloe barbadense*
nīoi	chili pepper	*Capiscum frutescens*
	clover	*Trifolium* spp.
Ferns		
		Lycopodium spp.
Grasses		
	American buffalograss	*Buchloe dactyloides*
	annual ryegrass	*Lolium multiflorum*
	blue panic	*Panicum antidotale*
	finger	*Digitaria eriantha*
	forage peanut	*Arachis glabrata*
	sandbur	*Cenchrus echinatus*
	green panic	*Panicum maximum* var. *trichoglume*
	lovegrass	*Eragrostis supurba*
	pangola	*Digitaria pentzii*
	plains bristlegrass	*Setaria leucopila*
	saltgrass	*Distichlis stricta*
	stylosanthes	*Stylosanthes fruticosa*
	tephrosia	*Tephrosia vogelii*
	Townsville lucerne	*Stylosanthes humilis*
	veldt	*Eragrostis calycina*

Appendix 7 (continued)

Hawaiian Name	*English Name*	*Latin Name*
Grasses, continued		
	weeping lovegrass	*Eragrostis curvula*
	yellow bluestem	*Bothriochloa ischaemum*

Appendix 8:

Alien Faunal Species Currently Present on Kaho'olawe

Hawaiian Name	*English Name*	*Latin Name*
	Argentine ant	*Iridiomyrmex humilis*
	barn owl	*Tyto alba*
	big-headed ant	*Pheidole magacephala*
	black rat	*Rattus rattus*
	carabid beetle	*Carabidae* spp.
	carpenter bee	*Xylocopa sonorina*
	cat (feral)	*Felis catus*
	cochroach	*Pycnoscelus indicus*
	crambid moth	*Spoledea recurvalis*
	crazy ant	*Paratrechina longicornis*
	earthworm	*Lumbricidae*
	emerald cochroach wasp	*Ampulex compressa*
	Gambel's quail	*Callipepla gambelii*
	green darner dragonfly (common)	*Anax junius*
	halticid sweat bee	*Lasioglossum* spp.
	harlequin cockroach	*Neostylopyga rhombifolia*
	honey bee	*Apis melifera*
	house finch	*Carpodacus mexicanus*
	house mouse	*Mus musculus*
	house sparrow	*Passer domesticus*
	ichneumonid wasp	*Polistes; Pachodynerus*
	isopod	*Porcellio laevis*
	Japanese bush-warbler	*Cettia diphone*
	Japanese white-eye	*Zosterops japonicus*
	lygaeid seed bug	*Lygaeidae* spp.
	monarch butterfly	*Danaus plexippus*

Appendix 8 (continued)

Hawaiian Name	*English Name*	*Latin Name*
	northern cardinal	*Cardinalis cardinalis*
	northern mockingbird	*Mimus polyglottus*
	nutmeg mannikin	*Lonchura punctulata*
	oribatid mite	*Oribatidae* spp.
	Polynesian rat	*Rattus exulans*
	praying mantid	*Mantidae* spp.
	red-crested cardinal	*Paroaria coronata*
	ridge-billed drepanid	*Xestospiza fastigialis*
	sky lark	*Alauda arvensis*
	spotted dove	*Streptopelia chinensis*
	tachinid fly	*Tachinidae* spp.
	warbling silverbill	*Lonchura malabarica*
	wasp	*Polistes* spp., *Pseudopterocheilus* spp.
	water boatmen	*Trichocorixa reticulata*
	white-lined sphinx	*Hyles lineata*
	zebra dove	*Geopelia striata*

Appendix 9:

Native Faunal Species Currently Present on Kaho'olawe

Hawaiian Name	*English Name*	*Latin Name*
'ā	brown booby	*Sula leucogaster plotus*
'akē'akē	band-rumped storm-petrel	*Oceanodroma castro*
'a'o	Newell's manx shearwater	*Puffins puffins newelli*
honu	green sea turtle	*Chelonia mydas*
hunakai	sanderling	*Calidris alba*
'īlio holo i ka uaua	Hawaiian monk seal	*Monachus schauinslandi*
kioea	bristle-thighed curlew	*Numenius tahitiensis*
koa'e kea	white-tailed tropicbird	*Phaethon lepturus dorotheae*
koa'e 'ula	red-tailed tropicbird	*Phaethon rubicauda rothschildi*
kōlea	Pacific golden plover	*Pluvialis dominica*
mōlī	Laysan albatross	*Diomedia immutabilis*
mo'o	gecko	*Gekkonidae* spp.
noio	black noddy	*Anous minutus melanogenys*
'ōpe'ape'a	Hawaiian hoary bat	*Lasuirus cinereus semotus*
'ou	Bulwer's petrel	*Bulweria balwerii*
pueo	short-eared owl	*Asio flammeus sandwichensis*
'ua'u kani	wedge-tailed shear water	*Puffins pacificus chlororhynchus*
'ūlili	wandering tattler	*Heteroscelus incanus*
	Achatinellid land snail	*Tornatellides kahoolavensis*
	antlion	*Distoleon wilsoni, D. perjurus*
	aquatic fly (ephydrid, sciarid, and muscid)	*Diptera*
	black-bellied plover	*Pluvialis squatarola*

Appendix 9 (continued)

Hawaiian Name	*English Name*	*Latin Name*
	chironomid midge	*Pelypedilum nubiferum*
	dragonfly	*Odonata*
	globe skimmer dragonfly	*Pantala flavescens*
	mirid plant bug	*Miridae* spp.
	Myrmeleontid antlions	*Distoleon* spp.
	pectoral sandpiper	*Calidris melantotos*
	sharp-tailed sandpiper	*Calidris acuminata*
	skink	*Scincidae* spp.
	sphecid wasp	*Ectemnius distinctus; E. mandibularis*
	springtail	*Collembola*
	Succineid snail	*Bradybaena similaris*
	tephritid seed fly	*Trupanea crassipes*
	vespid wasp	*Pseudopterocheilus congruus*
	wasp	*Ectemnius* spp.
	yellow-faced bee	*Hylaeus obscurata*

Appendix 10: **Suggested Native Faunal Species to (Re)introduce to Kaho'olawe**

Hawaiian Name	*English Name*	*Latin Name*
'ā	masked booby red-footed booby	*Sula dactylatra personata* *Sula sula rubripes*
ae'o	black-necked stilt Hawaiian stilt	*Himantopus mexicanus knudseni,* *H. knudseni*
'akē'akē	band-rumped storm-petrel	*Oceanodroma castro*
'alae ke'oke'o	American coot	*Fulica americana alai*
'alae 'ula	common moorhen	*Gallinula chloropus sandvicensis*
'amakihi	Maui honeycreeper (yellow & greenish)	*Hemignathus virens wilsoni*
'apapane	honeycreeper (crimson & black)	*Himatione sanguinea*
'auku'u	black-crowned night heron	*Nycticorax nycticorax*
'ewa'ewa	sooty tern	*Sterna fuscata oahuensis*
honu 'ea	hawksbill turtle	*Eretmoshelys imbircata*
'io	Hawaiian hawk	*Buteo solitarius*
'iwa	great frigatebird	*Fregata minor palmerstoni*
kōloa	Hawaiian duck	*Anas wyvilliana*
nēnē	Hawaiian goose	*Branta sandvicensis*
oloma'o	Lāna'i thrush	*Myadestes lanaiensis*
'ua'u	Hawaiian dark-rumped petrel	*Pterodroma phaeopygia sandwichensis*
	Laysan duck	*Anas laysanensis*
	Laysan finch	*Telespiza cantans*
	millerbird	*Acrocephalias familiaris kingi*
	Nihoa finch	*Telespiza ultima*

Appendix 11: **Hawaiian Glossary**

Hawaiian	*English (Latin)*
ʻaʻaliʻi	(shrub) (*Dodonaea viscoca*)
aeʻo	Hawaiian stilt (bird) (*Himantopus mexicanus knudseni*)
ahu	altar, shrine
Ahupū	ʻili (and beach) in north-central Kahoʻolawe
ahupuaʻa	land division, extending from the uplands to the sea
ʻāina	land, living earth
ʻakēʻakē	ruddy turnstone (bird) (*Arenaria interpres*)
ʻakiʻaki	(grass) (*Sporobolus virginicus*)
ʻakoko	(shrub) (*Chamaesyce celastroides*)
ʻākulikuli	(herb) (*Sesuvium portulacastrum*)
ʻalae keʻokeʻo	Hawaiian coot (bird) (*Fulica americana alai*)
ʻalae ʻula	Common moorhen (bird) (*Gallinula chlorpus sandwicensis*)
ʻalauahio	Hawaiian honeycreeper (bird) (*Loxops maculata*)
ʻAleʻale	cliffs along the south, central coast of Kahoʻolawe
ʻamakihi	Hawaiian honeycreeper (bird) (*Loxops virens*)
ʻāweoweo	Hawaiian bigeye (fish) (*Priacanthus* spp.); (grass) (*Chenopodium oahuense*)
ʻemoloa (kāwelu)	(grass) (*Eragrostis variabilis*)
ha	to breathe, exhale
Hakioawa	ʻili and kahua kauhale on eastern shore of Kahoʻolawe
hala	pandanus, screw pine (tree) (*Pandanus odoratissimus*)
halapepe	(tree) (*Pleomele auwahiensis*)
Haleakalā	mountain located in east Maui
hau	a native tree of the hibiscus family
heiau	place of worship
heiau hoʻoulu ua	A rain attraction device
hinahina	(herb) (*Heliotropium anomalum* var. *argenutm*)
Honokanaiʻa (Hanakaniʻa)	ʻili, kahua kauhale, and Navy base camp on the southwest shore of Kahoʻolawe
honu	green sea turtle (*Chelonia mydasi*)
Honuaʻula	District of Maui that traditionally included Kahoʻolawe
hoʻōla hou i ke kino o Kanaloa	Give new life to the body of Kanaloa
hunakai	sanderling (bird) (*Calidris alba*)
ʻike pāpālua	See Chapter 2
ʻili	subdivision of an ahupusʻa

Appendix 11 (continued)

Hawaiian	*English (Latin)*
ʻiliahi	sandalwood (tree) (*Santalum freycinetianum*)
ʻilima	(shrub) (*Sida fallax*)
ʻīlio holo i ka uaua	Hawaiian monk seal (*Monachus schauinslandi*)
ipu	bottle gourd (vine) (*Lagenaria siceraria*)
ʻiwa	frigate (bird) (*Fregata minor palmerstoni*)
Kahekili	Maui chief during Vancouver's visit to the island in 1793
kahu	caretaker
kahua hoʻomoana	campsite
kahua kauhale	educational and cultural center, work camp
kamani	*Calophyllum* spp. (tree)
kalo	taro (herb) (*Colocasia esculenta*)
Kanaloa	primary Hawaiian deity, alternative name for Kahoʻolawe
Kanapou	ʻili in eastern Kahoʻolawe
Kaneloa	Gulch on Kahoʻolawe
kapa	bark cloth (tapa)
ka poʻe kahiko	people of old
Kaukamoku	Bay on northwestern shoreline, ʻili of Ahupū
Kaukaukapapa	beach near the western tip of Kahoʻolawe
Ka wai ola a Kāne.	The lifegiving water of Kāne
kāwelu	(grass) (*Eragrostis variabilits*)
Keoneuli	beach at Kanapou in eastern Kahoʻolawe
kī	ti (shrub) (*Cordyline terminalis*)
kiawe	mesquite (tree) (*Prosopis pallida*)
Kihei	(Maui place)
kino	body or the physical, non-spiritual form
kioea	bristle-thighed curlew (bird) (*Numenius tahitiensis*)
kīpuka	isolated patch of native vegetation
kō	sugar cane (*Saccharum officinarum*)
koaiʻa	(tree) (*Acacia koaia*)
kōkua	assistance
kōlea	Pacific golden plover (bird) (*Pluvialis fulva*)
koloa	Hawaiian duck (*Anas wyvilliana*)
koʻokoʻolau	(shrub) (*Bidens menziesii; B. molokaiensis*)
kou	(tree) (*Cordia subcordata*)
Kūheʻeia	Bay and kahua kauhale on north-central shore of Kahoʻolawe
kukui	candlenut (tree) (*Aleurites mouccana*)
Kūkulu ke ea a Kanaloa	The life and spirit of Kanaloa builds and takes form.

Appendix 11 (continued)

Hawaiian	*English (Latin)*
kula	a traditional Hawaiian cultivation style from the big island
Kula	district on Maui
kūmū	goatfish (*Parupeneus porphyreus*)
kūpuna	ancestors, elders
lā'au lapa'au	medicinal plants
Lae o Ka'ule	eastern point of Kaho'olawe (north edge of 'ili Kanapou)
Lae o Kealaikahiki	western point of Kaho'olawe
lauhala	mats woven from hala (pandanus) leaves
laulima	many hands working together
limu kala	seaweed (*Sargassum echinocarpum*)
limu 'ele'ele	seaweed (*Enteromorpha* spp.)
lōkahi	unity, harmony
Lonoikamakahiki	new year festival and ceremonies in honor of Lono
Lua Keālialalo	crater in the western interior of Kaho'olawe; "the pit of the low swampy land"
Lua Keālialuna	crater in the northwestern interior of Kaho'olawe; "the pit of the upper marshy land"
Lua Makika	crater at the of Kaho'olawe; "mosquito hole"
mai'a	banana (tree) (*Musa xparadisiaca*)
makai	toward the ocean
mālama	stewardship, caring
māmane	(tree) (*Sophora chrysophylla*)
ma'o	Hawaiian cotton (shrub) (*Gossypium tomentosum*)
Maui Nui	the islands of Maui, Moloka'i, Lāna'i, and Kaho'olawe; formerly on land mass and share similar ecosystems
mauka	toward the uplands
milo	(tree) (*Thespesia populnea*)
nā po'e Hawai'i	the Hawaiian people
naio	(shrub) (*Myoporum sandwicensis*)
naulu	sudden, showery wind from the sea, generally without clouds
naupaka kahakai	(shrub) (*Scaevola sericea*)
nēnē	Hawaiian goose (*Nesochen sandwicensis*)
niu	coconut (tree) (*Cocos nucifera*)
Oawawahie	beach in 'ili Hakioawa (northeast portion of Kaho'olawe)
ohai	(shrub) (*Sesbania tomentosa*)
'ohana	extended family
'ōhi'a 'ai	mountain apple (tree) (*Eugenia malaccensis*)
'ōhi'a lehua	(tree) (*Metrosideros macropus*)

Appendix 11 (continued)

Hawaiian	*English (Latin)*
olonā	shrub (*Touchardia latifolia*)
olopua	(tree) (*Nestegis sandwicensis*)
ʻōpeʻapeʻa	Hawaiian hoary bat (*Lasiurus cinerenus semotus*)
ʻopihi	limpet (*Cellana* spp.)
paka	tobacco (herb) (*Nicotiana tabacum*)
palani	surgeonfish (*Acanthurus dussumieri*)
Palupalu o Kanaloa	Hawaiian name for *Kaneloa kahoolaweensis*
pāpio	young ulua (crevalle, jack, or pompano) (fish)
piko	Center, fontanel, navel
pili	(grass) (*Heteropogon contortus*)
pōhuehue	(vine) (*Ipomoea pes-caprae*)
pueo	Hawaiian short-eared owl (*Asio flammeus sandwicensis*)
Puhi mai, e Kanaloa, na mea maikaʻi no ke ola hou o kou kino!	Grant us, Kaneloa, the good things needed to restore your physical manifestation!
pule ua	rain chant
puʻu	hill
puʻuhonua	place of refuge, sanctuary
Puʻu Koaʻe	islet off of ʻAleʻale (south-central Kahoʻolawe)
Puʻu Moaʻulaiki	hill in the central-northeast of Kahoʻolawe
Puʻu Mōiwi	hill in the center of Kahoʻolawe
ʻuala	sweet potato (*Ipomoea batatas*)
ʻuaʻu	dark-rumped petrel (bird) (*Pterodroma phaeopygia sandwichensis*)
ʻuhaloa	(herb) (*Waltheria indica*)
uhi	yam (*Dioscoreas alata*)
uhu	parrotfish (*Scarius perspicillatus*)
ulei	
ʻūlei	(shrub) (*Osteomeles anthyllidifolia*)
ulua	crevalle, jack, or pompane (fish)
ʻūlili	wandering tattler (bird) (*Heteroscelus incanum*)
ʻulu	breadfruit (tree) (*Artocarpus altilis*)
uluhe	(fern) (*Dicranopteris linearis*)
Waikahalulu	mauka of Honokanaiʻa on the western end of Kahoʻolawe
Wailuna	mauka of Hakioawa on the eastern end of Kahoʻolawe
wauke	(shrub) (*Broussonetia papyrifera*)
wiliwili	(tree) (*Erythrina sandwicensis*)